PRINCE WILLIAM SOUND

COMMERCIAL HARVEST OF PACIFIC HERRING, 1984-1987

By

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Fishery Research Bulletin No. 88-08

Alaska Department of Fish and Game
Division of Commercial Fisheries
Juneau, Alaska

December 1988

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ACKNOWLEDGMENTS

The authors express their gratitude to the Alaska Department of Fish and Game (ADF&G) staff who participated in the data collection; Linda Brannian and Brian Bue for their biometrics advice; and to Linda Brannian, Charles P. Meacham and Dennis G. Haanpaa for their review of the manuscript.

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ABSTRACT

During the management years 1984-87, the total Pacific herring, Clupea harengus pallasi, harvest utilization in the Prince William Sound management area ranged from 6,090.4 tonnes (6,713.4 tons) in 1984 to 11,317.7 tonnes (12,475.5 tons) in 1986 (mean = 8,274.4 tonnes). The purse seine sac roe harvest accounted for the major portion of the total harvest and utilization (mean percent = 75.8%), while the adult herring biomass utilized for the natural spawn-on-kelp harvest accounted for the smallest portion (mean percent = 3.4%). Total annual value of the herring fisheries to the fishermen ranged from approximately $4.9 million in 1984 to $9.7 million in 1986 (mean = $7.3 million).

Samples of Pacific herring were obtained from the commercial harvest of the bait and food fishery, the purse seine and gill net sac roe fisheries, the pound kelp fishery, and a variety of test samples. Year class dominance of the Pacific herring bait and food harvest was variable throughout the reporting period, except that the spring sac roe and pound fisheries were mainly dominated by the 1980 and 1981 year classes.

Pacific herring collected from the bait and food harvest were significantly smaller at age than samples obtained from the purse seine sac roe harvest. These results suggest that the biomass which supports the bait and food harvest may have been a distinct stock or a substock of the primary Prince William Sound spawning biomass. The gill net sac roe fishery selected for the larger and older-aged herring of the biomass and for the largest herring of the youngest year classes which arrived later on the spawning grounds than older individuals. Within an age class, larger herring arrived earlier on the spawning grounds than their smaller siblings and were spatially segregated by age. Male herring were more numerous than female herring in the newly recruited age-3 herring biomass. In years of strong 3-year-old herring recruitment, proportion of age-3 male herring also increased in the pre-spawning biomass with time subsequent to the initiation of the sac roe fishery.

KEY WORDS: Pacific herring, *Clupea harengus*, Prince William Sound, harvest summary, age-sex-size

INTRODUCTION

Age, sex, and, size composition of Pacific herring *(Clupea harengus pallasi)* in the commercial harvests and test catches landed in the Prince William Sound management area has been routinely summarized by the Alaska Department of Fish and Game (ADF&G). McCurdy (1986) originally reported most of the data summaries for the years 1973 through 1983. However, McCurdy (1986) reported all age-9 and older fish in a single category as "9+". Sandone (1988a) re-examined these data in order to derive the age compositions for the 1973 through 1983 sampled herring for age-9 and older fish. The age-sex-size data summaries for years 1984 through 1987 were reported by Sandone (1988b). The future development of management plans and options, as well as refinement of current strategies employed in the management of the Prince William Sound herring stock, rely on the continued assimilation of these annual data into the Pacific herring data base.

The specific objectives of this report were to:

(1) provide a summary of the various fisheries and test fishing activities which occurred during the reporting period;

(2) determine if herring size and age-class composition differ between the purse seine sac roe and the other commercial fisheries; and

(3) examine temporal and spatial aspects of the sex composition of the spawning herring biomass.

The Prince William Sound Management Area encompasses all coastal waters located in the northcentral Gulf of Alaska between Cape Sucking and Cape Fairfield (Figure 1). This management area is further divided into four management districts: Northern (Figure 2), Montague (Figure 3), Eastern, (Figure 2) and General (Figure 1). The herring fisheries of the Prince William Sound area include: (1) a fall-winter bait and food fishery, (2) purse seine and gill net sac roe fisheries; and 3) a spawn-on-kelp fishery which includes a natural spawn-on-kelp and a pound spawn-on-kelp fishery. Changes to the regulations concerning fishing seasons (5 AAC 27.330) and guideline harvest levels (5 AAC 27.360) have occurred on an annual basis for the years 1984 through 1987. Regulations governing the Prince William Sound Area commercial herring fisheries during this period can be found in the 1984 through 1987 editions of the Commercial Herring Fishing Regulations (ADF&G 1984, 1985, 1986, and 1987).

In 1977 the Northern, Montague, and General Districts were established in order to separate gear types fishing within the management area (Pirtle 1978). The sac roe fishery (no delineation as to gear types) was restricted to the Northern and Montague Districts. The General District, which consisted of all waters of the sound exclusive of the Northern and Montague Districts, was reserved for the bait and food fishery. In 1980 the Eastern District was established in order to facilitate management of the sac roe fisheries (Randall et al. 1981). Additionally, the gill net sac roe fishery was established as a separate fishery and restricted to the Northern District. In 1985, however, the regulations restricting the sac roe

fisheries to specific districts were eliminated. The bait and food fishery remained restricted to the General District (ADF&G 1985). Since 1986 the Prince William Sound Pacific herring fisheries have been managed as single stock (Alaska Board of Fisheries 1986). Therefore, the four management districts, as defined above, are currently of little use except for delineating general areas of Prince William Sound.

The management of a single Prince William Sound herring stock has simplified management. Under the single stock concept there is no longer a need to manage separate areas of the sound for specific exploitation rate or harvest guideline. Additionally, the single stock concept affords the manager more flexibility in the overall management of the resource. However, if more than one stock of herring exits in Prince William Sound, harvest strategies under the single stock scenario may result in stocks of herring being underutilized or overexploited.

A guideline harvest level of 0 - 20% overall exploitation rate of the total Prince William Sound estimated spawning biomass has been established. Annual, specific guideline harvest levels for each fishery are established prior to the fall bait and food season and are based on the previous year's final biomass estimate, cohort analysis, and projected age-class recruitment to the sac roe fishery (Alaska Board of Fisheries 1986). Additionally, a minimum spawning biomass threshold of 6,350 tonnes (7,000 tons), or 25% of the long-term (1974-1985) average peak biomass, has been established. Commercial fishing for Pacific herring is allowed only if the estimated spawning biomass is greater than the threshold level. A maximum exploitation rate of 20% may be allowed when the total biomass is greater than approximately 38,556 tonnes (42,500 tons) (Alaska Board of Fisheries 1986). At this level the Prince William herring stock is considered able to sustain a 20% exploitation. If, however, the estimated herring biomass declines below 38,556 tonnes (42,500 tons) resulting in the total harvestable surplus falling below 7,711 tonnes (8,500 tons) (20% exploitation of 38,556 tonnes), the herring harvest will be restricted based on the department's assessment of the status of the stock. Additionally, each fishery will be managed based upon on a percentage of their previous allocation. The percentage of the reduced estimated total harvestable surplus for each fishery is as follows:

bait and food	16.4%;	
natural spawn-on-kelp	9.7%;	
pound spawn-on-kelp	12.5%.	
purse seine sac roe	58.1%;	and
gill net sac roe	3.4%	(Alaska Board of Fisheries 1986).

The bait and food fishery is the first fishery to occur in the herring management year, July 1 - June 30. This fishery opens by regulation on September 1 and may extend through January 31. However, the fishery is closed by emergency order authority if the annual harvest level is attained prior to January 31. The maximum harvest level for the bait and food fishery is a fixed allocation of 1,270 tonnes (1,400 tons) of herring. Legal gear for this fishery includes purse seines, gill nets, and trawls (ADF&G 1987).

The two spawn-on-kelp fisheries, the natural kelp fishery and the herring pound kelp fishery, are separately managed. The harvest method now in use for the natural kelp fishery, diving and cutting the kelp frond 10.2 cm (4 in) above the stem, appears to have had minimal impact on healthy stands of kelp (Alaska Board of Fisheries 1986). Herring pound fisheries use purse seines to collect ripe herring. The captured herring are transferred from the purse seine into a net pen through the use of net doors. After the web around the door of purse seine and net pen has been laced together the volume of water enclosed by the purse seine is reduced, forcing the herring to swim through a web tunnel into the net pen. The web door of the pen is raised and closed after the herring swim into the pen, completing the transfer. The net pen is then towed to the pound site where the herring are transferred from the net pen into the pound in similar fashion. Before the transfer of herring into the pound occurs, however, fronds of harvested local ribbon kelp *Laminaria* sp. or imported *Macrocystis* sp. are suspended vertically from lines secured from the sides of the pound. The kelp fronds serve as the spawning substrate for the herring. The herring are confined in the pound until spawning activity has ceased. After spawning the herring are released and the spawn-on-kelp product is harvested. Since herring also spawn on the webbing of the pound web, the pound must remain in the water until the herring embryos attached to the pound structure have hatched. (Alaska Board of Fisheries 1986). Although herring are released after spawning, mortality is thought to be high due to stress, tissue damage, and scale loss which occurs during the confinement period. For management purposes, mortality of the pounded herring is assumed to be 100%.

The natural kelp and pound fisheries have fixed guideline harvest allocations. These allocations, however, have varied annually. The natural spawn-on-kelp allocation decreased from 169.6 tonnes (187.0 tons) of spawn-on-kelp in 1984 (ADF&G 1984) to 93.4 tonnes (103.0 tons) in 1987 (ADF&G 1987), while the pound spawn-on-kelp allocation increased from 23.6 tonnes (26.0 tons) of spawn-on-kelp in 1984 (ADF&G 1984) to 77.1 tonnes (85.0 tons) in 1987 (ADF&G 1987). The annual increase in the guideline harvest allocation for the pound spawn-on-kelp fishery was the result of the Alaska Board of Fisheries response to increased public participation in this fishery.

Prior to the 1987 season, herring pound operators were required to obtain a permit from the Commissioner of the Alaska Department of Fish and Game. Limits on the herring biomass and kelp used in the individual pound operation were stipulated in these permits. In December, 1986 the Commercial Fisheries Entry Commission (CFEC) limited the participants in the 1987 and future herring pound fisheries to those persons who participated in the fishery as the holder of a gear license or an interim-use permit prior to January 1, 1987. The maximum number of CFEC permits for the fishery was set at 125.

In order to determine an overall exploitation rate for the commercial herring fisheries the assumed amount of herring mortality plus the loss of herring reproductive potential resulting from the spawn-on-kelp fisheries are added to the actual harvested tonnage of adult herring in the bait and food and sac roe fisheries. From 1980 to 1986 the herring biomass utilized in the pound herring fishery was determined from visual estimates of the herring in the pounds. In 1987, however, this utilized biomass was estimated directly from the harvested spawn-on-kelp product. The herring

biomass utilized in the natural spawn-on-kelp has been estimated from the tonnage of the harvested spawn-on-kelp product since the inception of the fishery. These estimates of the adult herring biomass used in the production of the natural and pound spawn-on-kelp product are based on a 8.0:1.0 and 12.5:1.0 biomass to product weight ratio, respectively. Therefore, in 1987 the combined allocation is approximately equivalent to the removal of 1,711.0 tonnes (1,886.0 tons) of herring from the spawning biomass. Both programs are regulated by emergency order authority (ADF&G 1986).

The harvest allocation of the sac roe fisheries when the harvestable biomass equals or exceeds 7,711 tonnes (8,500 tons) consists of the remainder of the harvestable surplus herring biomass after subtracting the actual bait and food harvest and the combined roe-on-kelp allocations. The purse seine and gill net sac roe fisheries are allocated 94.5% and 5.5%, respectively, of the remaining, available herring biomass surplus (ADF&G 1987). In order to prevent gear conflicts, the gill net sac roe fishery normally follows the closure of the purse seine sac roe fishery (Alaska Board of Fisheries 1986). Participation in both sac roe fisheries is governed by the Commercial Fisheries Entry Commission. The maximum number of CFEC permits for the purse seine and gill net sac roe fisheries is 105 and 25, respectively.

METHODS

During 1984-87 samples of Pacific herring were randomly collected from commercial purse seine bait and food harvests, commercial purse seine and gill net sac roe harvests, ADF&G test beach seine and trawl catches, and industry-volunteered test purse seine catches. Total sample size of most samples collected during the 1984 management year was less than 300 fish per fishery opening or test set catch per area. Some individual samples consisted of less than 100 usable data sets (age, sex, and size data from individual fish) after accounting for illegible, regenerated, or missing scales. Sample size objectives were increased to 600 total individuals per commercial harvest opening or test set catch per area in 1985 in order to improve the accuracy of age-class composition estimates. Data collected from samples included the sex, standard length (mm), round weight (g), and age of individual specimens. Ages were determined from scales read under various magnification on commercial micro-fiche readers. Herring scale annulus formation was assumed to take place in the spring of the year, or coincidental with the sac roe fisheries. Therefore, the herring captured in the fall-winter bait and food fishery were from 5 to 10 months older than the corresponding sac roe herring of the same age in the same management year. Because of this aging format and management year delineation, the bait and food herring samples were from the year class one year earlier than the sac roe samples of the same age collected in the same management year. For example, in the 1986 sac roe fishery, age-4 herring were from the 1982 year class. However, in the chronologically earlier 1986 bait and food fishery, which occurred in the winter period of 1985-86, age-4 herring would be from the 1981 year class.

Calculation of the individual age-class contribution (percent by number) to the various herring fisheries varied with the fishery and/or with the number of samples taken. When only one sample was obtained from a particular fishery harvest (e.g., area-wide gill net harvest), or when multiple samples could not be identified with a particular catch within the fishery harvest, the sample, or the combined sample, and the fishery harvest age composition were assumed to be the same. However, when individual samples were obtained from specific identifiable catches within a fishery harvest, the age composition of the fishery harvest was calculated based on number of fish harvested. Total weight of each catch was converted to numbers of fish using the average weight of fish sampled from that catch. Total number of fish per individual catch was converted to numbers for each age class based upon the corresponding sample age frequency distribution. Numbers of fish harvested in each catch were summed across age classes. The total age contribution to a harvest by percent, was calculated from the total numbers of each age divided by the total number of fish harvested for all ages for that particular fishery.

The Prince William Sound herring management year commences on July 1. Therefore, for the purposes of this report the harvest year will also commence on July 1.

Exploratory graphical analysis of the mean length at age between the purse seine sac roe and the gill net, bait and food, and pound herring harvests indicated that mean length at age differed between fisheries. Purse seine sac roe samples were used as a base for comparisons because: (1) purse seines were assumed to be a non-selective gear type for all sizes of herring, (2) the purse seine sac roe harvest accounted for the bulk, 59.8% to 86.9%, of the total Prince William Sound harvest during the period 1984-87 (Table 1), and (3) the purse seine sac roe harvest occurred coincidentally when a high proportion of the total herring biomass was on the spawning grounds. The purse seine sac roe sample was assumed to represent the age, sex, and size composition of the bulk of the total spawning biomass. Likewise, the purse seine pound fishery samples were also assumed to be representative of the available biomass present on the grounds during the usually later-timed pound fishery. The purse seine bait and food harvest samples, however, due to questions concerning the size distribution of the herring in the water column and the possible size selectivity of the fishermen, may not have represented the Prince William Sound herring biomass during the fall and winter months when this fishery occurred.

Because unsubstantiated differences in mean length at age were noticed between fisheries, we wanted to test the hypothesis that there were no differences among the mean length of the major age classes (age 3-9) between fisheries. An analysis of variance (ANOVA) was conducted using a general linear model (GLM) approach for an unequal cell size (Freund and Littell 1981). A full factorial model was used due to the lack of parallelism observed for some years in the graphical depiction of mean length at age by fishery. The model used was:

$$\text{Length} = \text{Fishery} + \text{Age} + \text{Fishery} * \text{Age}.$$

Tests for homogeneity of variance were conducted (F-max test) and the variances were found to be homogeneous for all planned ANOVA. Additionally, multiple comparisons of mean lengths between fisheries were also conducted for each of the major ages. Least-squared estimates of marginal means (LSMEANS) were employed (SAS 1985). This was especially important if the original significance test of the ANOVA resulted in a significant interaction term which confounded the difference due to fishery and age. An analysis of simple effects for comparisons of mean length between the fisheries paired by age remained to describe any differences between fisheries.

An ANOVA between the purse seine and gill net sac roe harvests was not performed due to the presence of empty cells (ages) in the design. Analyzing multi-factor data with empty (or missing) cells usually gives results of questionable value since the data contain insufficient information to estimate the parameters of the model (Freund and Littell 1981). However, median length at age comparisons were completed using the Mann-Whitney-Wilcoxon test for equal medians. A non-parametric test was employed due to a possible non-normal distribution of the gill net data due to probable net selectivity (Brian Bue, ADF&G, Anchorage, personal communication).

Age composition of the various harvest samples were compared using contingency tables which calculated a chi-square statistic (STSC 1985). Since the purse seine sac roe harvest samples were considered to represent a high proportion of the total herring biomass, the age composition of this harvest sample was considered a base of comparisons for all harvest sample age-composition comparisons. Due to the above-mentioned problem associated with the year class differences at age between the purse seine sac roe and bait and food harvests, year-class compositions were compared. Differences between age frequency distributions of test fishing samples within a year were also determined using contingency tables. Extreme age class samples containing less than five observations were pooled.

The relationship between the sex composition of the various commercial and test purse seine and beach seine samples and time relative to the initiation of the annual sac roe harvest was explored using linear regression techniques. Gill net-caught samples were precluded from the regression analysis due to possible sex-related selectivity of the gear. Comparisons of sex ratios were completed using a chi-square test for proportions (Snedecor and Cochran 1980).

Significance level for all tests was set at 10%. The Bonferroni inequality was used to set the comparisonwise error rate (CER) for all simultaneous comparisons being made with LSMEANS or medians. The CER became the ratio of the ã over C, the number of simultaneous comparisons being made (SAS 1985). In general, C was the number of major age classes compared between two fisheries in a particular year. Therefore, the significance level for simultaneous comparisons of the estimators was: $\alpha/C = 0.1/C$.

RESULTS

The following season summaries highlight the bait and food, sac roe, and spawn-on-kelp fisheries which occurred in the Prince William Sound management area from 1984 through 1987. Additional specific information concerning these fisheries can be found in the annual Prince William Sound finfish management report (Randall et al. 1984, 1985a, 1986 and Brady et al. 1987, 1988)

1984 Season Summary (July 1, 1983 - June 30, 1984)

Bait and Food Fishery

The 1984 Pacific herring bait and food fishery opened and closed by regulation on September 15, 1983 and January 31, 1984, respectively (Table 2). Weak demand for herring bait and food resulted in light fishing effort in the food and bait fishery. The 1984 herring bait and food harvest of 248.2 tonnes (273.6 tons) (Table 1) was the smallest harvest of record except for harvest of the 1977-78 season. Only 2 purse seine vessels participated in the fishery (Table 2) (Randall et al. 1984). The bait and food harvest accounted for 4.1% of the total herring harvest for 1984. The total harvest was obtained from eastern Prince William Sound in the vicinity of Knowles Head (Figure 2). The estimated value of the harvest was approximately $65,300 (Randall 1984).

Four samples of Pacific herring from the bait and food fishery, totaling 216 individuals, were obtained for age, sex, and size analysis. The 1979 (age 4) and 1980 (age 3) year classes dominated the commercial catch, contributing 43.1% and 41.2%, respectively, to the bait and food harvest (Figure 4). Male to female sex ratio of sampled herring was 1.16:1 (Sandone 1988b).

Herring sampled from the bait and food harvest appeared smaller at age than herring sampled from the sac roe harvests (Figure 5, Figure 6, Table 3). Additionally, the curves of the mean length at age of the bait and food and sac roe fisheries (Figure 5) were not parallel over the range of interest (ages 3-8). Results of the ANOVA (Table 4) supported the conclusion drawn through inspection of the data. The interaction term was highly significant, confounding the significant effect due to the fishery term. Multiple pairwise contrasts were made for the mean length at age between fisheries. All comparisons of the LSMEANs, except for age-3 herring, were significantly ($P \leq 0.0167$) different between fisheries (Table 5). Analysis of the year-class composition of the two harvest samples also indicated significant differences between the two fisheries (Table 4). These results suggested the possibility of at least two distinct stocks contributing to the Prince William Sound Pacific herring harvest. However, if there indeed existed only one stock of herring in Prince William Sound, the differences in length (at age) and age compositions of the two harvest samples (purse seine sac roe and bait and food) suggested that the samples obtained from the bait and food harvest were not representative of the herring population in the fall and winter months.

Sac Roe Fishery

Purse Seine Sac Roe Fishery. The 1984 purse seine sac roe fishery was managed on a emergency order basis. Fishing for Pacific herring using purse seines was allowed in the Montague District on April 14 for two separate periods. Actual fishing time was 3.0 h. The total purse seine sac roe harvest for the two periods totaled 5,295.2 tonnes (5,836.9 tons) (Table 1). During the season 105 boats participated in the fishery (Table 2); 101 boats made at least one delivery. Average roe recovery was between 10-11% (Randall et al. 1985a). The purse seine harvest accounted for 86.9% of the total herring harvest in 1984. Estimated value of the fishery was $4,437,900 (Table 2).

Samples from the commercial purse seine harvest were obtained from catches in Stockdale Harbor and Rocky Bay (Figure 3) within the Montague District. The 1980 year class (age 4) dominated both samples, contributing 45.1% to the total purse seine harvest. The 1981 year class (age 3) accounted for a relatively strong 21.5% of the total purse seine sac roe harvest (Figure 7). Conspicuously absent from the dominating role from 1979 through 1983 was the 1976 year class (age 8), which accounted for only 6.0% of the total harvest (Figure 7). The contribution of the 1976 year class in the 1984 purse seine sac roe harvest was most likely dampened due to the strong recruitment of the 1980 and 1981 year classes into the fishery. Male to female herring sex ratio in the Stockdale Harbor and Rocky Bay harvest samples were 0.84:1 and 1.18:1, respectively (Sandone 1988b).

Gill Net Sac Roe Fishery. The 1984 gill net sac roe fishery commenced on April 18 for a scheduled 24-h opening in the Montague District. However, the fishery was closed by emergency order after 5 h of fishing due to unacceptably low roe recovery rates. An extremely high incidence of male herring in the early deliveries was the probable cause of the low roe recovery rates. The herring harvest for this 6-h opening was approximately 76.5 tonnes (84.3 tons) (Randall et al. 1985a).

After test fishing appeared to have located a herring biomass with an even sex ratio and with roe recoveries above 10%, a second opening was announced for fishing on April 20. However, due to uncertainty concerning the stability of the high test roe recoveries, fishing time was limited to 6 h and confined to the waters adjacent to Storey Island in the General District (Figure 2). Early reports during this second opening indicated that roe recoveries were acceptable (10% - 12%). Later that same day the opening was extended for an additional 24 h. Catches during this initial extension were limited by inclement weather. Therefore, an additional 24-h extension was announced on April 21. Herring harvested in the Storey Island area accounted for approximately 76% of the total 1984 commercial gill net harvest of 311.1 tonnes (342.9) (Table 1). Reported roe recoveries varied between 8% and 14%. Ex-vessel value was estimated at $170,000 (Table 2). A total of 24 fishermen participated in the fishery (Randall et al. 1985a). The gill net sac roe harvest accounted for 5.1% of the total 1984 herring harvest.

Pacific herring samples from the initial Montague District gill net sac roe harvest was dominated by the 1976 (age 8) and 1977 (age 7) year classes. These two year classes contributed 40.8% and 33.6%, respectively, to this

relatively small harvest. Sex ratio of the sample supported the early harvest reports of a sex ratio dominated by males. The male to female ratio was 1.43:1. Sample size consisted of 265 individuals (Sandone 1988b).

Pacific herring samples were also obtained from the Storey Island commercial gill net harvest. During the three days which gill net fishing was allowed, 228 individual herring were sampled for age, sex, and size composition. As in the initial gill net sample, the 1976 and 1977 year classes dominated the harvest, contributing 36.0% and 32.5%, respectively, (Sandone 1988b) to the harvest sample. The Storey Island harvest sample, however, contained a higher proportion of males than the earlier Montague District sample. Male to female sex ratio was 1.75:1. The combined weighted contribution of the 1976 and 1977 year class to the total gill net harvest was 37.2% and 32.7%, respectively (Sandone 1988b) (Figure 8).

Age composition of the gill net sac roe harvest was significantly different from the purse seine sac roe harvest (Table 4). The absence of the 1980 and 1981 year classes from the gill net harvest, albeit dominating the purse seine sac roe harvest, indicated the selectivity of the gill net gear for larger-sized, older herring. In other words, due to the relatively large mesh size of the commercial gill nets, these younger age classes were not susceptible to capture. Additionally, the relatively few gill net-caught herring from the younger age classes appeared larger than purse-seine caught herring of the same cohort (Figure 5, Table 3). Statistical analysis of the median length at age of sac roe herring indicated that gill net-caught herring were significantly ($P \leq 0.0167$) larger than purse seine-caught herring for the youngest age classes represented in the gill net sample (ages 4, 5 and 6) but not significantly different for herring age 7 fish and older (Table 6). These results indicated that only the larger fish of the younger age classes were susceptible to capture by this gear type. Additionally, these results suggested that herring did not fully recruit to the gill net fishery until age 7.

Spawn-On-Kelp Fishery

Natural Spawn-On-Kelp Fishery. The natural spawn-on-kelp fishery remained closed throughout the season. Due to the dispersed spatial and temporal distribution of the herring spawn, either the egg coverage on the kelp or the species of kelp which received egg deposition was not of marketable quality. Additionally, 40.8 tonnes (45.0 tons) of *Macrocystis* kelp was imported to Prince William Sound for "open pounding". If harvested, this product would have been part of the natural harvest quota. At least 18.1 tonnes (20.0 tons) of kelp were lost due to shipping, poor handling, and bad timing. The remaining 22.7 tonnes (25.0 tons) were placed in open pounds, but due to the above-mentioned factors concerning the herring spawn, the "open pound" *Macrocystis* kelp was, likewise, not harvested (Randall et al. 1985a).

Pound Spawn-On-Kelp Fishery. In 1984, 65 individuals were issued permits to operate a pound for the production of spawn-on-kelp. However, only 45 participants actually constructed pounds by the April 1 deadline (Table 7) and participated in the fishery. The 1984 harvest guideline for this fishery was set at 23.6 tonnes (26 tons) of spawn-on-kelp (ADF&G 1984). Pounds were initially constructed in Landlocked, Boulder and Galena Bays

(Figure 2). By the season's end, the majority of the effort was concentrated in Galena Bay where 93% of the harvest was produced. The remainder of the harvest was produced in Boulder Bay and Jack Bay (Figure 2). Seining of herring for stocking into pounds was opened on April 24 in designated areas of Galena, Boulder and Landlocked Bays. At the close of the seining on May 8, a total of 37 pounds had produced a total estimated unprocessed harvest weight of 24.2 tonnes (26.7 tons) (Table 7). Imported *Macrocystis* kelp comprised 64% of the harvest, 15.5 tonnes (17.1 tons). The local ribbon kelp *(Laminaria)* accounted for the remainder, 8.7 tonnes (9.6 tons). The total value of the fishery was approximately $270,000 (Randall et al. 1985a) (Table 7). The estimated herring biomass utilized in the pound fishery was between 235.9 and 326.6 tonnes (260.0 and 360.0 tons), or approximately 3.9% of the total 1984 herring harvest (Table 1).

Three samples, totaling 432 individuals, were obtained from captured pound herring. The age composition of the pound fishery sample (Figure 9) paralleled (non-statistical comparison = NSC) the purse seine sac roe harvest sample (Figure 7). Herring samples were collected from pounds operating in Boulder Bay and Galena Bay. Similar to the purse seine sac roe sample, the 1980 and 1981 year classes dominated the combined pound fishery sample, accounting for approximately 44.7% and 24.5%, respectively, of the pounded herring (Figure 9). Male herring were more numerous than female. Male to female sex ratios ranged from 1.75:1 in the Boulder Bay sample to 1.92:1 in the Galena Bay sample (Sandone 1988b).

Age composition of the pound fishery did not significantly deviate from the purse seine sac roe fishery composition (Table 4). In addition, the curves of mean length at age of the purse seine sac roe and pound fisheries (Figure 5) were parallel (NSC) except at the extreme ages indicating similar growth rates. These similarities suggest that the fish captured in these two fisheries were from one stock of herring. However, ANOVA of the two purse seine fisheries indicated that the interaction term and the fishery effect on mean length of the herring captured were significantly different (Table 4). Again, the significance of the interaction term confounds discussion of the significant difference due to the fishery effect. Further, LSMEANS comparisons indicated that only 2 of the 7 age classes compared were significantly ($P \leq 0.0143$) different. The purse seine pound herring were smaller than the sac roe samples in those significantly different age classes (Table 5). Note that differences in mean size at all ages may have existed in these two populations but due to small sample sizes of the older ages (Table 3) a difference may not have been detected. These results suggest that smaller fish at age arrived later on the spawning grounds than their larger siblings because the pound fishery, which had smaller fish at age, occurred latter than the purse seine sac roe fishery. However, the statistical argument supporting this hypothesis is weak due to the above-mentioned confounding factors.

Test Fishing Activities

Pre-season stock assessment in the Northern District, using test trawl surveys, revealed an age composition dominated by year classes 1981 (age 4) and 1980 (age 3). These young year classes contributed 52.8% and 34.7%, respectively to the test trawl sample. Male to female ratio, 0.95:1, was near equal in the sample of 72 herring (Sandone 1988b).

Test fishing with commercial purse seine gear was conducted prior to the purse seine sac roe fishery in the vicinity of Port Gravina (Figure 2) on April 3 and 6 and Stockdale Harbor on April 10 and 13. The 1980 (age 4) and 1981 (age 3) year classes dominated the samples from the two areas. In the Port Gravina sample the 1980 and 1981 year classes contributed 45.8% and 35.4%, respectively, to the sample. Similar contributions of the 1980 (44.0%) and 1981 (34.6%) year classes, were also observed in the Stockdale Harbor test sample (Sandone 1988b). However, male to female sex ratios varied. In the Port Gravina sample females slightly outnumber males, male to female sex ratio 0.94:1, while in the Stockdale Harbor sample males outnumbered females 1.48:1 (Sandone 1988b).

1985 Season Summary (July 1, 1984 - June 30, 1985)

Bait and Food Fishery

The 1985 Pacific herring bait and food fishery opened and closed by regulation on September 15, 1984 and January 31, 1985, respectively (Table 2). Depressed statewide crab fisheries and poor food markets continued to depress effort in this fishery. During the 1985 bait and food fishery only three purse seine vessels participated (Table 2). All harvests were taken from the Knowles Head area in eastern Prince William Sound. The total bait and food harvest of 926.9 tonnes (1,021.7 tons) accounted for 11.2% of the total 1985 Prince William Sound herring harvest (Table 1). Three buyers processed the catch. Ex-vessel value of the fishery was approximately $243,700 (Table 2).

A single sample of Pacific herring, consisting of 611 individuals, was collected from the bait and food harvest. The 1980 year class (age 4) dominated the harvest, accounting for approximately 42.7% of the sample. The 1979 year class (age 5), was the next dominant year class, contributing 26.8% to the harvest. Year classes 1978 (age 6) and 1981 (age 3) also accounted for a substantial portion of the harvest, contributing 12.3% and 11.5%, respectively, to the harvest sample (Figure 4). Females slightly outnumbered male herring. The male to female ratio was 0.90:1 (Sandone 1988b).

Comparison of the 1985 purse seine bait and food sample to the purse seine sac roe harvest samples appeared similar to results obtained in 1984 comparisons. Year-class composition of the two purse seine harvests were significantly different (Table 4). Mean length of the bait and food herring also appeared smaller at age than the sac roe fishery samples (Figure 10, Figure 11, Table 8). Likewise, the mean length-at-age curves (Figure 10) of the two harvest samples appeared to diverge. ANOVA indicated that the size of the herring harvested in these two fisheries were significantly different (Table 4). However, the significance of the fishery effect was again confounded by a highly significant interaction term (Table 4). LSMEAN comparisons of length at age indicated significant ($P \leq 0.0143$) differences in all contrasted ages (Table 9). Age 3 through 9 of the bait and food harvest sample were significantly smaller than the corresponding purse seine sac roe ages even though the bait and food herring were approximately 9 months older than the sac roe samples. These results, in

conjunction with the 1984 results, further support the suggestion of the existence of two distinct stocks or a continued problem of obtaining a representative sample of the fall and winter herring biomass.

Sac Roe Fishery

Purse Seine Sac Roe Fishery. As in 1984, the 1985 purse seine sac roe fishery was managed on an emergency order basis. Fishing with purse seine gear was allowed for two separate openings on April 28 and 29 for a total fishing time of 4.0 h. The initial opening of 3 h fishing time was confined to the Unakwik Inlet and Wells Bay area of the General District (Figure 2). During this opening, 4,407.6 tonnes (4,858.5 tons) (Randall et al. 1985b) of herring were harvested by 90 purse seine vessels. The 15 buyers which bought herring consistently reported roe recovery in excess of 10% throughout the period (Randall et al. 1986).

The second opening occurred in a confined area of Stockdale Harbor and Port Chalmers (Figure 3). The relatively small area opened to fishing was an attempt to limit the catch to within harvest guidelines. During this 1-hr opening, 2,015.4 tonnes (2,221.5 tons) of herring were harvested (Randall et al. 1985b). Roe recovery was between 10% and 12% (Randall et al. 1986).

A total of 102 out of 103 permit holders made at least one delivery during the two periods. The combined ex-vessel value of the 1985 purse seine sac roe fishery was approximately $5.2 million (Table 2) (Randall et al. 1986). The total purse seine sac roe harvest of 6,423.1 tonnes (7,080.3 tons) accounted for 77.5% of the total 1985 Prince William Sound herring harvest (Table 1).

During the commercial purse seine openings in the vicinity of the north shore and Montague Island areas, samples of harvested herring were obtained for age, sex, and size analysis. The 1980 (age 5) and 1981 (age 4) year classes dominated the harvest sample. These two strong year classes contributed 35.7% and 24.2%, respectively, to the purse seine sac roe harvest. The 1979 year class (age 6) accounted for 13.0%. The 1976 year class (age 9), which dominated all sac roe harvests from 1979 through 1983, contributed 11.9% (Figure 7). Male herring were outnumbered by females in both the Stockdale Harbor (0.86:1) and Port Chalmers (0.80:1) samples (Sandone 1988b).

The surprisingly strong contribution of the 1976 year class to the 1985 sac roe herring harvest, after contributing very little to the 1984 purse seine sac roe harvest (Figure 7) was puzzling. A number of possible reasons have been suggested to account for the low contribution of the 1976 year class to the 1984 purse seine fishery, including the combination of changes in the migrational patterns, the timing of the fishery, sampling error and location of the harvest (Richard Randall, Alaska Department of Fish and Game, Anchorage, personal communication).

Gill Net Sac Roe Fishery. The commercial gill net sac roe fishery commenced only 3 h after the close of the second purse seine sac roe opening. The gill net fishery also occurred in the same area as the second purse seine opening, Stockdale Harbor. Initially, this gill net sac roe opening was scheduled for 24 h. However, based upon catch rate and desired

harvest, the opening was extended for an additional 10 h. The total gill net harvest of 374.9 tonnes (412.3 tons), 4.5% of the total 1985 Prince William Sound herring harvest (Table 1), was landed by 21 gill net vessels (Table 2). Average roe recovery, based on the reports of the four buyers on the grounds, was 11-12%. Ex-vessel value of the gill net harvest was $384,000 (Table 2) (Randall et al. 1986).

One sample of 509 fish was collected during the gill net herring harvest. Year classes 1976 (age 9) and 1980 (age 5) co-dominated the harvest sample, accounting for 26.3% and 27.7%, respectively, of the sample. Other year classes which substantially contributed to the gill net sac roe harvest were the age-4 1981 year class (19.3%), the age-8 1977 year class (10.6%), and the age-7 1978 year class (9.6%) (Figure 8). Female herring outnumbered males approximately 4 to 3, for a male to female ratio of 0.76:1 (Sandone 1988b).

Although the purse seine and gill net fisheries occurred at nearly the same time, highly significant differences in age composition occurred (Table 4). Additionally, age-4 through age-7 gill net-caught herring were significantly ($P \leq 0.0125$) larger than purse seine-caught sac roe herring (Table 6). Similar results were also noted in the comparison between samples obtained from gill net and purse seine-caught sac roe herring in 1984. These results further supported the suggestion that the commercial gill nets used in Prince William Sound select for the older aged and, therefore, larger herring and larger individuals of the younger age classes. The absence of the 1981 year class (age 4) from the commercial gill net catch, while substantially contributing to the purse seine sac roe harvest, indicated that recruitment into the Prince William Sound gill net fishery occurred at age 5 at the earliest. These data also suggested that full recruitment of Pacific herring to the 1985 gill net fishery occurred at age 8.

Spawn-On-Kelp Fishery

Natural Spawn-On-Kelp Fishery. The 1985 guideline harvest for this fishery was set at 153.3 tonnes (169.0 tons) (ADF&G 1985). Two openings were scheduled in 1985 for the natural spawn-on-kelp fishery. On May 6, Valdez Arm and Port Fidalgo (Figure 2) were opened for a 6-hr test opening. During this period, 9.8 tonnes (10.8 tons) of wild spawn-on-kelp were harvested (Randall et al. 1985b). Due to poor quality of the product (Randall et al. 1986), however, buyers on the grounds refused to buy a large portion of the harvest. On May 8 a second opening was scheduled for 14 h on Naked Island and on the north shore area around Fairmount and Olsen Islands (Figure 2). An estimated 8.9 tonnes (9.8 tons) of spawn-on-kelp were harvested (Randall et al. 1985b). However, a large portion of this harvest was also rejected by buyers due to poor quality. A combined total of 34.1 tonnes (37.6 tons) of spawn-on-kelp was harvested and sold by 107 divers. An estimate of the spawn-on-kelp wastage was unavailable. Value of the fishery to the participants was approximately $36,600 (Table 7) (Randall et al. 1986). Estimated biomass of herring utilized by this fishery was 149.9 tonnes (165.2 tons), or 1.8% of the total 1985 Prince William Sound herring harvest (Table 1).

Pound Spawn-On-Kelp Fishery. A total of 81 permits were issued for the 1985 pound spawn-on-kelp fishery. However, only 59 individuals constructed pounds by the April 1 deadline (Table 7). The distribution of the 1985 total allocation of 36.3 tonnes (40.0 tons) (ADF&G 1985) yielded an individual pound production limit of 680 kg (1,500 lb) of spawn-on-kelp (Randall et al. 1986).

The pound fishery was initially centered in Galena Bay. Seining of herring for introduction into pounds was opened on April 25. At that time, however, few pounds were ready to accept herring due to late arrival of the imported *Macrocystis* kelp. Most of the pound operators used *Macrocystis* as a spawning substrate. Additional areas, including Boulder, Sawmill and Jack Bays (Figure 2) were opened to seining after the herring had dispersed from Galena Bay. These areas, however, did not provide enough herring to fill all the pounds. On May 4, Naked Island was opened to seining for pound herring. Thirty-seven pounds were towed to Naked Island (Figure 2). Thirty of these pounds were successful in producing the spawn-on-kelp product. The pounds operating in the Naked Island area accounted for approximately 63% of the total pound spawn-on-kelp production (Randall et al. 1986).

The total season harvest of 36.5 tonnes (40.2 tons) of spawn-on-kelp was produced from 50 pounds. Spawn on *Macrocystis* comprised 70% of the harvest, while spawn on *Laminaria* accounted for the remainder. Total value of the fishery to the fishermen was approximately $570,000 (Table 7) (Randall et al. 1986).

Based upon visual estimates of herring biomass in the pounds, between 408.2 and 499.0 tonnes (500.0 and 550.0 tons) of herring were utilized in this fishery. Using the lower bound of the estimate, the 1985 pound fishery accounted for 4.9% of the total herring harvest in Prince William Sound (Table 1).

Samples for sex, age, and size analysis were taken from pounds operating in Galena Bay, 579 individuals, and in the vicinity of Naked Island, 520 individuals. Male to female sex ratios in both the Galena Bay (0.99:1) and Naked Island sample (0.96:1) were near even (Sandone 1988b).

The herring biomass used by the pound fishery was dominated by the 1980 (age 5) and 1981 (age 4) year classes. These year classes contributed approximately 36.9% and 29.4%, respectively, to the utilized biomass. Year classes 1979 (age 6) and 1976 (age 9) accounted for 10.5% and 8.3%, respectively, of the sample. The 1982 year class (age 3) accounted for 7.9% of the sample (Sandone 1988b) (Figure 9).

Statistical analysis (Table 4) of the age compositions of the combined purse seine sac spawn (Figure 7) and pound samples (Figure 9) indicated that the age compositions of the two harvest samples were significantly different. Due to the high number of samples collected from each fishery (1,127 and 1,090, respectively), the contingency table test for differences between the age composition of the fishery samples was extremely sensitive to relatively slight differences between samples. ANOVA, however, indicated that the length of the herring captured in the purse seine sac roe and pound fisheries did not significantly differ (Table 4). Inspection of the mean length at age curves (Figure 10) indicated (NSC) that the curves were

not parallel which resulted in a significant interaction term in the ANOVA (Table 4). As in prior years, the significance of the interaction term confounded the discussion of the fishery effect on mean herring length. However, LSMEAN length at age comparisons indicated that only one of the nine ages contrasted was significantly ($P \leq 0.0111$) different (Table 9). These results suggested that the differences between the two fisheries were minor. The similarity between the purse seine sac roe and pound harvest samples was primarily attributed to the spatial and temporal overlap of the two fisheries. The purse seine pound fishery sample was obtained in Galena Bay, 3 d prior to the initiation of the sac roe fishery, and from Naked Island, 6 d after the termination of the sac roe fishery. The purse seine sac roe fishery samples were obtained from the north shore and the Montague Island area only 1 d apart.

Test Fishing Activities

A single test purse seine sample was obtained near Granite Bay on April 25, immediately prior to the purse seine sac roe opening. As in the test beach seine and commercial purse seine sac roe and pound samples, this catch was also dominated by the 1980 and 1981 year classes. These year classes accounted for 34.9% and 27.7%, respectively, of the test catch. Male to female sex ratio, 1.09:1, was slightly skewed towards the males (Sandone 1988b).

One ADF&G beach seine sample was collected in St. Matthew's Bay (Figure 2) on April 21. Mean size data was not available from this sample. Although four year classes contributed substantially to the sample, this test sample was also dominated by the 1980 and 1981 year classes. These year classes accounted for 34.2% and 36.0%, respectively, of the sample. Year classes 1979 and 1982 each contributed 13.7% to the test catch. Male and female herring were represented near equally (Sandone 1988b).

1986 Season Summary (July 1, 1985 - June 30, 1986)

Bait and Food Fishery

The 1986 Pacific herring bait and food fishery opened by regulation on September 1, 1985 and was closed by Emergency Order on February 15, 1986 (Table 2). The season opened two weeks earlier due to the results of Alaska Board of Fisheries action during the fall of 1984 (ADF&G 1985). The season was also extended by two weeks. The bait and food fishery normally closed on January 31, however due to requests submitted by several local fishermen and local processors, a two week extension was permitted to allow them to take advantage of some late developing markets. Bait markets were weak early in the season due to depressed statewide crab fisheries. Sales to food markets remained minimal until late in the season (Randall et al. 1986).

The herring bait and food harvest for the 1986 season was 1,014.3 tonnes (1,118.1 tons) (Table 1). Participation included 6 purse seine vessels (Table 2), however, only 5 permit holders made at least one delivery. All harvests were landed in the vicinity of Knowles Head in the eastern portion

of Prince William Sound. Six local buyers processed the harvest (Randall et al. 1986). The 1986 bait and food harvest accounted for 9.0% of the total 1986 herring harvest in Prince William Sound (Table 1). Ex-vessel value of the bait and food harvest was estimated to be approximately $210,000 (Table 2).

Six separate samples obtained throughout the bait and food fishery were analyzed for sex, age, and size composition. Number of fish per sample ranged from 117 to 662. Total number of herring sampled was 2,475 individuals. Year classes 1981 (age 4), 1982 (age 3), and 1980 (age 5) accounted for 29.1%, 21.5% and 18.3%, respectively, of the combined harvest samples. Year classes 1983 (age 3) and 1979 (age 6) also contributed substantially to the harvest, accounting for 13.1% and 10.2%, respectively, of the combined samples (Figure 4). Overall, female herring slightly outnumbered male herring, resulting in a male to female sex ratio of 0.95:1 (Sandone 1988b). As in prior years, mean length of bait and food herring appeared smaller than herring captured in the sac roe fisheries (Figure 12, Table 10) and mean length-at-age curves appeared to diverge (Figure 13).

As in 1984 and 1985 comparisons, year-class composition comparisons between the purse seine sac roe and bait and food fisheries yielded significant differences (Table 4). Likewise, ANOVA also indicated a significant size difference in herring captured from the purse seine sac roe versus the bait and food fisheries (Table 4), but the significant interaction term (Table 4), again, confounded the argument. Multiple mean comparisons using LSMEANS comparisons, however, indicated that the herring captured in the bait and food fishery were significantly ($P \leq 0.0111$) smaller at age than herring sampled from the purse seine sac roe harvest for all age classes compared (Table 11). Interestingly, as in 1984 (Figure 6) and 1985 (Figure 11), the difference between the mean length at age appeared to increase relative to age (Figure 13). This apparent divergence suggested differential growth rates. In conjunction with the continued trend of significantly smaller fish being harvested in the fall and winter bait and food fishery, the possibility of different growth rates existing for the herring captured in these two fisheries further suggests a two-stock theory. However, these differences could also be attributed to the failure of obtaining samples representative of the fall and winter herring population.

Sac Roe Fishery

Purse Seine Sac Roe Fishery. The 1986 purse seine sac roe fishery was opened for a single 3-h period on April 17. Location of the fishery was restricted to a section of the General District which included Unakwik Inlet and Wells Bay. A much larger than expected harvest of 8,915.9 tonnes (9,830.0 tons) (Table 1) was landed by 105 purse seine vessels (Table 2). The 14 buyers on the grounds reported an average roe recovery of 10-11%. Estimated ex-vessel value of the purse seine sac roe harvest was approximately $7.8 million (Table 2) (Brady et al. 1987).

The 1986 purse seine harvest was sampled from catches landed in the vicinity of Mueller Cove and Fairmount Island (Figure 2 and Sandone 1988b). The combined sample consisted of 1,280 herring. As in 1984 and 1985, the strong 1980 (age 6) and 1981 (age 5) year classes continued to dominate the harvest. These year classes contributed 35.4% and 31.8%, respectively, to

the 1986 purse seine sac roe harvest. No other year class contributed more than 9.0% to the harvest sample. It is interesting to note, however, that the 1976 year class (age 10), which dominated the 1979 through 1983 sac roe fisheries, contributed a relatively strong 7.4% to the harvest (Figure 7). Male to female sex ratios were nearly even in the Mueller Cove (0.99:1) and Fairmount Island (1.06:1) samples.

Gill Net Sac Roe Fishery. The 1986 gill net sac roe herring harvest was accomplished through multiple openings in three widespread areas of Prince William Sound. An initial 12-h opening was announced on April 24 for the Port Fidalgo area. However, the period was closed after 7 h due to a sharp decline in the roe recovery rates and the available herring biomass. A small harvest of 22.7 tonnes (25.0 tons) was taken during the open period. A subsequent opening in the vicinity of Montague Island on April 25 yielded 161.5 tonnes (178.0 tons) in 46 h of fishing time. The balance of the harvest was obtained from a 36-h opening on the north shore in the vicinity of Granite Bay (Figure 2). Mean roe recovery was 11.4% (Brady et al. 1987). The total gill net sac roe harvest of 407.0 tonnes (448.6 tons) accounted for 3.6% of the total 1986 Prince William Sound herring harvest (Table 1). Six buyers and 25 fishermen participated in the fishery. Estimated value of the fishery was $408,600 (Table 2) (Brady et al. 1987).

Pacific herring samples were obtained from gill net harvests landed in the vicinity of Port Fidalgo, Montague Island and Wells Bay. Each sample was dominated by the 1980 and 1981 year classes. These year classes contributed 42.6% and 18.3%, respectively, to the combined gill net harvest sample. Year classes 1979 and 1976 also accounted for a substantial portion of the harvest, 14.8% and 9.6%, respectively, of the weighted sample (Figure 8). Male to female sex ratio varied from 0.89:1 in the Montague Island sample to 1.29:1 in the Port Fidalgo sample (Sandone 1988b).

As in prior years, the contingency table test indicated that there were significant differences between the age composition of the gill net and purse seine sac roe harvests (Table 4). However, unlike previous years' analyses, the median length-at-age comparisons between the two sac roe gear types indicated that herring captured by gill nets were significantly ($P \leq 0.0111$) smaller at age for ages 6-8 and 10 than purse seine sac roe samples (Table 6). These results were in contrast to prior years' analyses which indicated that gill nets selectively caught the larger fish of the represented younger age class. However, due to the timing of the 1986 gill net fishery, it appeared that the median length-at-age analysis supported the hypothesis that smaller fish at age arrive latter on the spawning grounds than their larger siblings. In effect, due to the delay in obtaining the gill net harvest (occurred from 7 to 11 days after the termination of the purse seine sac roe fishery) the large fish of each age class may have migrated from the area leaving the late arrivals of each age class to support the fishery. Another possibility is that the gill net fleet fished in 1986 with a smaller mesh size than in previous years, therefore eliminating the larger fish from susceptibility to capture. However, the presence of significantly smaller fish at age 6-8 and 10, in conjunction with the presences of the usually observed differences in age-class composition between purse seine (Figure 7) and gill net sac roe (Figure 8) fisheries, tend to refute this explanation.

Spawn-On-Kelp Fishery

Natural Spawn-On-Kelp Fishery. The 1986 guideline harvest for this fishery was set at 128.8 tonnes (142.0 tons) of spawn-on-kelp (ADF&G 1986). Two areas were opened for the harvest of natural spawn-on-kelp. The majority of the harvest of spawn-on-kelp, 42.6 tonnes (47.0 tons), was obtained from a 86-h opening in Wells Bay (Figure 2) from April 30 through May 3. Effort was relatively light; 29 divers participated in the fishery (Table 7). A second very short opening for the harvest of spawn-on-kelp occurred in the Galena Bay area (Figure 2) on May 4. The harvest for this 8-h harvest period was less than 0.5 tonnes (0.6 tons). Three buyers participated in the fishery. Overall quality of the product was considered above average. Value of fishery to the fishermen was approximately $160,000 (Table 7) (Brady et al. 1987). The estimated herring biomass utilized by this fishery, 341.1 tonnes (376.0 tons), accounted for 3.1% of the total 1986 Prince William Sound herring harvest (Table 1).

Pound Spawn-On-Kelp Fishery. A total of 104 pound permits were issued for pounding operations in 1986. Only 82 individuals, however, constructed pounds by the April 1 deadline (Table 7) and qualified for an individual allotment from the harvest guideline of 54.4 tonnes (60.0 tons) (ADF&G 1986). The individual pound production limit for each qualified pound operators was 663 kg (1,463 lb) of spawn-on-kelp (Brady et al. 1987).

All 82 pounds were successful in producing the spawn-on-kelp product. The season total harvest of 64.4 tonnes (70.1 tons) was composed entirely of *Macrocystis*. The overall quality of the product was far superior than previous years (Brady 1987). The estimated value of the fishery was $1.15 million (Table 7) (Brady et al. 1987).

The 1986 pound fishery was located in Galena Bay. Galena Bay was opened to the seining of herring for pound use from April 21 to April 28. Visually estimated herring biomass utilized in this fishery ranged from 635.0 tonnes to 725.8 tonnes (700.0 and 800.0 tons) (Brady et al. 1987). Pacific herring utilized by the 1986 pound fishery was approximately 5.6% of the total herring harvest (Table 1).

A single sample of 670 herring was obtained from the Galena Bay pound fishery. As in the purse seine sac roe fishery, the pound fishery sample was dominated by the 1980 (age 6) and 1981 (age 5) year classes. These year classes contributed 31.0% and 34.9%, respectively, to the total pound herring sample. The 1982 year class (age 4), accounted for 14.2% of the pound herring sample (Sandone 1988b) (Figure 9). This contribution was nearly double the 7.4% observed in the purse seine sac roe sample. Male to female herring sex ratio, 0.86:1, was skewed toward the females (Sandone 1988b). Pound herring were generally smaller (NSC) than purse seine sac roe herring (Figure 12, Table 10) and the mean length at age curves of the two fisheries appeared parallel (Figure 12).

Statistical analysis of the purse seine pound and the sac roe fishery indicates that the age compositions were significantly different (Table 4). Additionally, ANOVA of the size of the herring harvested in these two fisheries was also significant (Table 4). Further, the interaction term

(fishery*age) was not significant. LSMEANS multiple comparisons at age between the purse seine sac roe and pound samples indicated that pound herring were significantly ($P<0.0125$) smaller than purse seine sac roe herring in five of the eight age classes compared (Table 11). The continued difference in age-class composition and length at age when these two fisheries are temporally segregated further supports the hypothesis that younger aged herring and smaller herring of the younger age classes arrive later on the spawning grounds than the older herring and larger herring of the same cohort, respectively. Since the 1986 pound herring sample was obtained 4 d after the purse seine sac roe fishery, and 3 d prior to the initiation of the gill net sac roe fishery, these results also support the explanation suggested for the relatively small size at age of the gill net-caught sac roe herring.

Test Fishing Activities

During April and May, 1986, the Department conducted test fishing activities throughout Prince William Sound in conjunction with the various spring sac roe fisheries. The first and only test fish catch using purse seine gear was conducted within Wells Bay immediately prior to the purse seine sac roe herring fishery. Although age composition was very similar (NSC) to the commercial purse seine sac roe samples, sex ratio was more skewed toward the males. Male to female sex ratio was 1.24:1 (Sandone 1988b).

Sampling with beach seine gear began in the north shore area in the vicinity of Olsen (April 12) and Fairmount Islands (April 15), where the first large aggregation of herring was sighted. After this initial test sample was obtained, sampling efforts were directed in a clockwise, chronological progression around the sound. Sampling sites included specific locations in, or in the vicinity, of Fish Bay, Irish Cove, Port Chalmers on Montague Island and Unakwik Point.

Test samples obtained near Olsen and Fairmount Islands consisted primarily of year classes 1980 (age 6) and 1981 (age 5). These major year classes contributed 32.3% and 35.1%, respectively, to the combined north shore area samples. Lesser but substantial portions of the combined samples, 9.9% and 5.5%, were contributed by the 1982 (age 4), and 1983 (age 3) year classes, respectively (Sandone 1988b). In later and more easterly combined test catch samples obtained within Port Fidalgo on April 23, specifically within Irish Cove and Fish Bay (Sandone 1988b), four year classes, 1980-83, combined to dominate the catch (Sandone 1988b). Particularly interesting was the large contribution of the 1982 (age 4) and 1983 (age 3) year classes to the samples. This large contribution of young-age fish indicated good recruitment to the spawning herring biomass. These two young year classes accounted for 53.8% of the total sample of 1,223 individuals. Although spatially separated but temporally close, the final two samples, collected at Port Chalmers on Montague Island on April 25 and Unakwik Point on April 27, located on the north shore, appeared similar with respect to age-class composition. The 1982 and 1983 year classes accounted for 21.4% and 17.5% in the Port Chalmers and Unakwik Point samples, respectively. The 1980 and 1981 year classes dominated each location sample, accounting for 63.8% and 61.4% of the respective catches (Sandone 1988b).

Statistical comparisons of the age-class compositions between all combinations of the north shore area, Port Fidalgo, Port Chalmers and Unakwik Point samples indicated that differences between all age distributions were highly significant (chi-square range = 30.0 - 354.7, $P<0.0001$, df=7). However, when the age distribution was grouped into 3 age groups (2-4, 5-7 and >8 years old) significant ($P\leq0.0167$) differences remained for only 4 of the 6 comparisons (Table 12). Nonsignificant differences ($P>0.0167$) were observed in age-group comparisons between the north shore area sample and Unakwik Point sample, and the Port Chalmers and Unakwik Point sample. Note that the north shore area and Unakwik samples were spatially closest, but temporally extreme, indicating that the influx of younger-aged herring documented in the Port Fidalgo samples had not occurred in the north shore or Unakwik area. Differences between age groups between the Port Fidalgo and all other samples remained highly significant (Table 12). These results in conjunction with the observed age compositions of the samples (Figure 14) indicated that a temporal as well as a spatial age-class distribution occurred in the Prince William Sound in 1986. It also appeared that in 1986, the youngest age classes, at least initially, congregated in the eastern portion of Prince William Sound.

1987 Season Summary (July 1, 1986 - June 30, 1987)

Bait and Food Fishery

The 1987 bait and food fishery opened by regulation on September 1, 1986 and was closed by Emergency Order on October 24, 1986 (Table 2). A total of 1,157.7 tonnes (1,276.1 tons) of herring was harvested for bait (Table 1). During the season, five purse seine vessels and three buyers participated in the fishery. Ex-vessel value of the fishery was $350,900 (Table 2).

Samples were obtained from the 1987 bait and food harvest on two separate days. Total number of individual herring sampled was 1,258. Three year class, 1981 (age 5), 1982 (age 4), and 1983 (age 3) dominated the harvest. These year classes contributed 24.3%, 25.0%, and 21.5%, respectively, to the combined samples (Figure 4). Male to female sex ratio in the combined samples was 0.91:1 (Sandone 1988b). As in prior year, the mean length at age of the bait and food harvest sample appeared smaller than the sac roe harvest samples (Figure 15, Table 13). Examination of the mean length-at-age curves suggested (NSC) that the curves were not parallel (Figure 16).

As in years 1984-86, the year class composition of the bait and food harvest was significantly different than the purse seine sac roe harvest year class composition (Table 4). ANOVA also indicated that the two fisheries were significantly different relative to herring size (Table 4). However, the interaction term was again significant, confounding the discussion of the fishery effect. Similar to previous years' analyses: (1) LSMEANS comparisons indicated that the bait and food herring sizes (at age) were significantly ($P\leq0.0125$) smaller than the purse seine sac roe herring sizes for all represented age classes (Table 14); and (2) there existed the possibility of different growth rates, as indicated by the continued divergent mean length-at-age curves (Figure 16). These results, in conjunction with prior years' analyses, further support the hypothesis that

smaller-at-age herring present in Knowles Head area during the fall and winter month may be a separate stock of herring or sub-stock of the total Prince William Sound spawning biomass. However, this conclusion was based on the assumption that the bait and food sample was representative of the overwintering herring biomass of Prince William Sound, which may not be valid.

Sac Roe Fishery

Purse Seine Sac Roe Fishery. Fishing for sac roe herring using purse seines was allowed for 1 h on April 8. The open area included waters in, or in the vicinity of, Wells, Cedar, Granite and Fairmount Bays and Fairmount Island (Figure 2). Approximately 2,812.3 tonnes (3,100.0 tons) of herring were harvested during this 1-h opening. On April 9, a 0.5-h opening in the same area opened during the prior fishing period, with the exception of Fairmount Bay, yielded a harvest of 1,620.2 tonnes (1,786.0 tons). Average roe recovery for the total harvest of 4,432.6 tonnes (4,886.0 tons) (Table 1) was 11%. Estimated value of the harvest was estimated at $5.3 million. Ninety-eight purse seine vessels (Table 2) participated in the fishery (Brady et al. 1988).

Three separate samples of Pacific herring were collected for age, sex, and size during the purse seine sac roe fishery. All samples were dominated by the 1980 (age 7) and 1981 (age 6) year classes. These two dominate year classes contributed approximately 30.9% and 25.9%, respectively, to the combined harvest sample (Figure 7). A relatively strong contribution, 16.5%, by the 1984 (age 3) year class indicated probable continued recruitment of herring to the 1988 Prince William Sound sac roe fisheries. Male to female herring sex ratio varied little, ranging from 1.09:1 to 1.13:1 in the three samples (Sandone 1988b).

Gill Net Sac Roe Fishery. The 1987 gill net sac roe fishery was opened for 24 h commencing on April 10 in the waters of Fairmount Bay. During this period, 24 gill net vessels harvested a record 493.0 tonnes (543.4 tons) of herring (Table 1). Average roe recovery was approximately 9.5%. The ex-vessel value of the harvest was estimated at $516,000 (Table 2) (Brady et al. 1988). The gill net harvest accounted for 6.7% of the total 1987 Prince William Sound herring harvest. This percentage was the highest portion of the Prince William Sound herring harvest caught by the gill net fleet (Table 1).

One sample consisting of 587 individuals was obtained from the gill net harvest in Fairmount Bay. Like the purse seine sac roe harvest sample, the gill net sample was dominated by the 1980 and 1981 year classes. The contribution of these two year classes to the gill net harvest was 36.2% and 26.6%, respectively (Sandone 1988b) (Figure 8). Unlike the purse seine sac roe harvest, however, the 1984 and the 1985 year classes were not represented, further supporting the hypothesis that recruitment to the gill net fishery occurs no earlier than age 5. Mean length at age of gill net-caught herring appeared larger at age for the younger age classes than the purse seine sac roe harvest (Figure 15).

Gill net and purse seine sac roe age-class compositions differed significantly. Median length at age comparisons indicated that the gill net

sac roe sample was significantly ($P \leq 0.0125$) larger at age for ages 5-7 (Table 14), and as in 1984 and 1985, the 1987 gill net harvest immediately followed the purse seine sac roe harvest. These results, similar to the 1984 and 1985 analyses, also suggest that the gill net fleet frequently harvested the larger individuals from the youngest represented age classes while also selecting for the older and larger individuals. Additionally, these data also suggested that full recruitment to the 1987 gill net fishery occurred at age 8.

Spawn-On-Kelp Fishery

Natural Spawn-On-Kelp Fishery. The 1987 natural spawn-on-kelp fishery was opened for two separate openings during the period April 15 to April 17 in Unakwik Inlet, Wells Bay, Cedar Bay, Granite Bay, Fairmount Bay and the waters surrounding Fairmount Island. Total harvest time totaled 48.0 h (Table 7). Approximately 79.9 tonnes (88.1 tons) were harvested during the two openings. Three processors and 69 divers participated in the fishery. The estimated value of the harvest was approximately $284,000 (Table 7) (Brady et al. 1988).

Pound Spawn-On-Kelp. The spawn-on-kelp in pounds fishery was limited by the Commercial Fisheries Entry Commission (CFEC) in December 1986. Although 147 persons applied for an ADF&G permit only 111 were eligible for CFEC permits and qualified for an allocation by constructing a pound frame by April 1 (Table 7).

Due to the relatively early arrival of the herring spawning biomass on the grounds and the late arrival of the *Macrocystis* kelp imported from Southeast Alaska, pound operators were not able to take advantage of the first pound seining opening on April 10 in Galena Bay. Additional areas, including Tatitlek Narrows, (Figure 2) Boulder Bay, and all of Port Fidalgo, were opened to the seining of herring for introduction into pounds. All but four of the pounds were filled with herring and producing spawn-on-kelp by the close of seining on April 21. Total harvest of pound spawn-on-kelp totaled 54.7 tonnes (60.3 tons) (Table 7). The vast majority of the harvest was composed of *Macrocystis*, with only a minor fraction of the total composed of locally harvested *Laminaria*. Quality of the product was below prior years due to below average egg coverage of the kelp. However, prices paid to the pound operators were quite high. Value of the total harvest was estimated to be $1.8 million (Table 7) (Brady et al. 1988).

Samples from the pounded herring were obtained from Boulder Bay on April 11 and 23, Port Fidalgo on April 13, and Two Moon Bay (Figure 2) on April 16. Only the sample taken in Boulder Bay on April 11 was not completely dominated by the 1984 year class (age 3). The 1984 year class accounted for 72.5% of the total of all pound herring samples (Figure 9). While the male to female sex ratio in the initial Boulder Bay sample was slightly skewed toward the males, 1.10:1, the sex ratio in the Port Fidalgo (1.43:1) and Two Moon Bay (1.45:1) samples was heavily skewed toward the males. Sex and size data for the latter Boulder Bay pound sample was unavailable (Sandone 1988b). This inordinate domination of the pound herring by males was probably the dominant factor which resulted in the below average quality of the spawn-on-kelp product in 1987.

The purse seine pound and sac roe harvest age compositions differed significantly from each other (Table 4). Additionally, ANOVA indicated that the size of the herring differed between the two fisheries (Table 4). However, due to the significance of the interaction term, the discussion of the significance of the fishery effect was, again, confounded. LSMEANS comparisons at age indicated that the pound herring were significantly ($P \leq 0.0111$) smaller at ages 3-5 (Table 14). The bulk of the older age classes in the combined pound herring samples was contributed by the Boulder Bay sample of April 11 (Sandone 1988b), which was conducted only 3 days after the purse seine fishery. Therefore, the time between the purse seine sac roe and pound fisheries may have not been adequate to observe significant changes in mean length at age for the older age classes. Additionally, age classes 8-12 were not represented in pound samples taken after April 11, and representation of ages 6 and 7 was extremely weak. Small sample sizes of these older age classes may have also contributed to the absence of significant differences between size at age of the two fishery harvests for older-aged herring. However, results from the LSMEANs comparison, in conjunction with the age-class composition analysis, further supports the hypothesis that younger and smaller fish at age arrive on the spawning grounds later than older or larger fish of the same age class.

Test Fishing Activities

ADF&G beach seine test fishing efforts consisted of two test sets in Fairmount Bay. The initial set was conducted prior to commercial fishery operations on April 6. As in the commercial samples, the 1980 (age 7) and 1981 (age 6) year classes dominated the sample, contributing 27.9% and 32.7%, respectively to the total sample. The relatively strong contribution (9.2%) of the 1984 (age 3) year class to the sample so early in the spawning migration indicated that the 1984 year class may supply added recruitment to future herring fisheries in Prince William Sound. Male to female sex ratio was 0.84:1 (Sandone 1988b).

The second test beach seine sample from Fairmount Bay was collected on May 8 after all commercial fisheries were terminated. The 1984 year class dominated, contributing 72.8% to the total sample. The 1980 and 1981 year classes, which dominated earlier samples, accounted for a combined contribution of only 11.5%. Additionally, in the May 8 sample, male herring outnumber females by at least 2:1 in all year classes with a sample size greater than 4 individuals. The dramatic increase in the male proportion of the population resulted in a male to female sex ratio sample of 2.35:1 (Sandone 1988b). These results suggested that as the season progressed, proportion of male herring in he pre-spawning biomass increased. This increase in the male:female sex ratio was due to either an actual increase in the proportion of males in the late arriving herring biomass or the possibility that male herring remained longer on the grounds than female herring.

The one test purse seine sample of 663 individuals was obtained on April 7 in Cedar Bay immediately before the commercial purse seine sac roe fishery (Sandone 1988b). Year class dominance appeared to parallel the commercial purse seine sac roe harvest. Male to female sex ratio, 0.90:1, was slightly lower than the purse seine sac roe harvest (Sandone 1988b).

Sex Ratio Investigations

When all sample sex ratios from 1984-87, excluding gill net samples, were plotted relative to the initiation of the annual purse seine fishery (day 0), a positive relationship between proportion of males in the spawning biomass and time was observed (Figure 17). Linear regression analysis explained only 40.0% of the variability in the data (R^2=0.40). However, the slope of the regression, 0.03, was significantly different from 0 (Student's t=4.76, $P \leq 0.0010$, df=32).

The degree of male dominance also depended upon the strength of the initially recruited biomass. For example, in 1985 and 1986 age-3 herring contributed 4.2% and 4.4%, respectively, to the total sac roe harvest. In those years, 3-year old male herring did not significantly outnumber female herring (chi-square=0.63, P>0.9000, df=1 and chi-square=0.74, P=0.3591, df=1, respectively). Additionally, a significant time-influenced relationship was not observed (Student's t=0.3637, P=0.4467, df=14) (Figure 18). However, the lack of such a relationship may be due to the limited temporal sampling during 1985 and 1986. Contrastingly, in 1984 and 1987, when the contribution of 3-year-old herring to the total sac roe harvest was 20.8% and 25.3%, respectively, a majority of the 3-year-old herring were male in each year (chi-square=2.85, P=0.0930 df=1; and chi-square=79.89, $P \leq 0.0050$, df=1, respectively). Additionally, the proportion of male herring in the 3-year-old population increased relative to the time of the initial annual sac roe fishery (Figure 18). The slope of the regression line, 0.02, was significantly different from 0 (Student's t=2.51, P=0.0244, df=16). Linear regression analysis, however, explained only 28.3% of the variability in the data (R^2=0.283). These results suggested that in years of significant recruitment of 3-year-old herring, that age-3 male herring outnumber female herring and the proportion of age-3 male herring in the pre-spawning biomass increases with the duration of the run.

DISCUSSION

The average lengths at age of Pacific herring sampled from the purse seine bait and food harvest were significantly smaller than samples obtained from the purse seine sac roe harvest. This difference was highly significant each year from 1984 through 1987, even though the bait and food herring samples were from 5 to 10 months older than the purse seine sac roe samples. A number of hypothesis have been offered to explain the smaller bait and food herring: (1) the herring biomass which contributed to the Prince William Sound fall and winter bait and food fishery is a separate stock or substock of the Prince William Sound herring spawning biomass; (2) the bait and food fishery has been selective for smaller herring; (3) the herring segregate in the water column by size, with the smaller individuals congregating near the surface and, therefore, are more available to the bait and food fishery; and (4) the smaller herring of each age group remain in Prince William Sound during the winter months. The significant differences observed in the age-class compositions and the apparent difference in growth rates of the herring from the two harvest samples do

not ultimately refute any of these hypotheses. Therefore, each hypothesis should be considered in the development of the management strategies for the bait and food fishery. Management strategies probably would not differ from present strategies if any or all of the latter three hypotheses were found to be true. However, if separate stocks or substocks of herring do exist in Prince William Sound, adjustments would need to be made, primarily to the harvest strategies of the bait and food fishery. If the two-stock concept is considered, the spring spawning stock may be slightly underutilized. However, the management implications regarding the fall-winter stock are unclear, and would necessarily be based on the estimated biomass and the temporal and spatial spawning location of this stock. Since the harvest guideline has been set at a fixed figure of 1270 tonnes (1,400 tons) the fall-winter stock may be overexploitated, underutilized, or, possibly, neither. Additionally, if the fall-winter stock is available for harvest during the spring sac roe fisheries, the total harvest of this stock may exceed the sustained harvest level for this stock.

A study designed to determine the size of the fall-winter biomass, as well as age structure, should be initiated so that harvest levels of the bait and food fishery can be adjusted if necessary. Since the herring schools are in deeper water during the fall and winter months, they must be assessed using hydroacoustic techniques. Additionally, this study should also be designed to obtain representative herring samples from different depth strata to answer the question concerning the distribution of herring by size in the water column. Sampling with trawl gear at different depths would provide representative samples. In addition to investigations regarding mean size at age and age class composition, growth rates of the sampled herring also need to be assessed. The results of such a study would have direct implications concerning the validity of the use of the food and bait harvest age-sex-size data for catch-at-age or "cohort analysis" (Pope 1972).

Although gill net herring gear selected for larger, and therefore older, individuals of the herring biomass, as well as for larger individuals of the younger age classes (ages 3 - 6 or 7), the small portion of the total herring harvest landed by gill net gear minimized the implications this fishery has on the overall management of the Prince William Sound herring stock. However, by regulating the stretch-mesh size of the gill net, managers could target a specific size range corresponding to a specific age group harvested by this fishery. A minimum stretch-mesh size would have the benefit of protecting smaller, younger fish from harvest.

Specific location as well as timing of a fishery may also have played an important role in determining the age-class composition of the fishery harvest. Younger-aged herring arrived on the spawning ground later than older individuals. Smaller herring at age arrived later on the spawning grounds than their larger siblings. In 1986, ADF&G herring samples taken from eastern Prince William Sound appeared to contain more individuals of the younger age classes than samples taken from north shore area samples. However, one year of data hardly represents a trend. Therefore, in order to ascertain where this observed phenomena is actually occurring, a study designed to determine the spatial segregation of herring by age within Prince William Sound should be initiated. This suggested study would require an extension of test fishing activities throughout the sound for a

slightly extended period of time after culmination of the sac roe and pound herring fisheries. Results of such a study would aid managers in targeting specific age groups for harvest or escapement.

Since the major products of the spring sac roe and spawn-on-kelp fisheries are based upon female herring, managers need to be aware of the impact of strong new recruitment to egg deposition, sex ratio and percent roe content. Proportion of male herring increase after the initiation of the sac roe fishery. This especially true when recruitment of 3-year-old herring is substantial. In years of strong 3-year-old recruitment to the spawning biomass, the sac roe and pound herring fisheries should target (temporally and spatially) on the older age classes of herring in order to maintain a near even sex ratio in the harvest. Sex ratio in favor of males result in a lower percent roe recovery and less egg deposition on the pound spawn-on-kelp product. Although recruitment of 3-year-old herring to the spawning biomass can not be accurately predicted based upon previous years biomass, early test samples may provide an indication of the relative strength of a newly recruited age class. Managers must be aware of potential newly recruited 3-year-old herring and direct the fisheries, if possible, toward areas and times when the contribution of this male-dominated age class is minimal in order to maximize value of the fishery to the fishermen.

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TABLES AND FIGURES

Table 1. Prince William Sound commercial bait and food and sac roe harvests and the estimated herring biomass utilized in the natural and pound spawn-on-kelp harvests, 1969-1987.

	Pacific Herring Harvest						Herring Utilization					
	Bait & Food [a]		Sac Roe				Pound Kelp [b]		Natural Kelp [c]		Total	
			Purse Seine		Gill net		Purse Seine					
Harvest Year	(tonnes)	(%)	(tonnes)	(%)	(tonnes)	(%)	(tonnes)	(%)	(tonnes)	(%)	(tonnes)	(%)
1969	0.0	0.0	322.6	94.4	0.0	0.0	0.0	0.0	19.2	5.6	341.9	100.0
1970	9.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	690.6	98.7	699.6	100.0
1971	18.1	0.5	833.9	22.9	0.0	0.0	0.0	0.0	2,791.6	76.6	3,643.7	100.0
1972	4.4	0.1	1,612.3	42.5	0.0	0.0	0.0	0.0	2,174.7	57.4	3,791.4	100.0
1973	7.7	0.1	6,336.1	85.0	0.0	0.0	0.0	0.0	1,111.5	14.9	7,455.3	100.0
1974	0.0	0.0	5,777.1	74.2	3.4	0.0	0.0	0.0	2,003.4	25.7	7,783.9	100.0
1975	0.0	0.0	5,517.1	62.4	0.0	0.0	0.0	0.0	3,328.0	37.6	8,845.1	100.0
1976	0.0	0.0	2,344.6	57.1	0.0	0.0	0.0	0.0	1,759.6	42.9	4,104.2	100.0
1977	0.0	0.0	2,071.0	57.8	1.5	0.0	0.0	0.0	1,513.2	42.2	3,585.7	100.0
1978	229.2	11.4	1,206.2	60.2	56.0	2.8	0.0	0.0	511.3	25.5	2,002.7	100.0
1979	1,170.2	17.6	3,754.5	56.5	0.0	0.0	0.0	0.0	1,717.1	25.9	6,641.8	100.0
1980	595.1	6.9	5,482.3	64.0	240.0	2.8	24.5	0.3	2,221.9	25.9	8,563.8	100.0
1981	1,285.0	8.8	12,492.5	86.0	212.8	1.5	99.8	0.7	444.2	3.1	14,534.3	100.0
1982	1,145.4	12.3	6,484.8	69.4	357.3	3.8	235.9	2.5	1,123.5	12.0	9,346.9	100.0
1983	801.2	17.2	2,471.4	53.1	95.6	2.1	181.4	3.9	1,100.2	23.7	4,649.9	100.0
1984	248.2	4.1	5,295.2	86.9	311.1	5.1	235.9	3.9	0.0	0.0	6,090.4	100.0
1985	926.9	11.2	6,423.1	77.5	374.9	4.5	408.2	4.9	149.9	1.8	8,282.9	100.0
1986	1,014.3	9.0	8,915.9	78.8	407.0	3.6	635.0	5.6	345.5	3.1	11,317.7	100.0
1987	1,157.8	15.6	4,432.6	59.8	493.0	6.7	683.8	9.2	639.7	8.6	7,406.7	100.0

[a] Gear type used includes purse seine, pair trawl, mid-water trawl, and otter trawl. Since 1982, however, purse seines have been used exclusively.

[b] From 1980-1986, the tons of herring shown are the lower bound of the herring biomass range estimate utilized by the commercial pound fishery. The herring biomass utilized in the 1987 pound fishery was based on the assumption that 1.0 tonne of spawn-on-kelp requires the utilization of approximately 12.5 tonnes of herring biomass.

[c] Based upon the estimated removal of the reproductive capacity from the population. Assumes that average herring roe recovery is 10% and that 80% of the wild spawn-on-kelp harvest weight consists of herring embryos.

Table 2. Prince William Sound commercial Pacific herring harvest estimated value, effort, duration, and/or period, 1984-1987.

	Bait and Food Harvest			Sac Roe Harvest							
	Purse Seine			Purse Seine				Gill Net			
Harvest Year	Estimated Value (X $1,000)	Effort (number of boats)	Period	Estimated Value (X $1,000)	Effort (number of boats)	Duration (hours)	Period	Estimated Value (X $1,000)	Effort (number of boats)	Duration (hours)	Period
1984	65.3	2	09/15/83 - 01/31/84	4,437.9	105	3.0	04/14	170.0	24	59.0	04/18 & 04/20 - 04/22
1985	243.7	3	09/15/84 - 01/31/85	5,200.0	103	4.0	04/28 & 04/29	384.0	21	34.0	04/29 - 05/01
1986	210.0	6	09/01/84 - 02/15/85	7,800.0	105	3.0	04/17	408.6	25	90.0	04/24 - 04/28
1987	350.9	5	09/01/86 - 10/24/86	5,300.0	98	1.5	04/08 & 04/09	516.0	24	24.0	04/10

Table 3. Sample size, mean length, and standard deviation at age of the Pacific herring samples obtained from the various commercial harvests, Prince William Sound, 1984.

	Purse Seine Bait & Food			Purse Seine Sac Roe			Gillnet Sac Roe			Purse Seine Pound		
Age	n	Mean Length (mm)	Standard Deviation	n	Mean Length (mm)	Standard Deviation	n	Mean Length (mm)	Standard Deviation	n	Mean Length (mm)	Standard Deviation
1	0			0			0			0		
2	0			1	151		0			0		
3	89	177	7.1	115	178	8.0	0			106	178	11.2
4	93	188	7.1	242	192	10.8	5	221	6.1	193	188	11.3
5	20	193	8.8	61	204	10.7	27	217	9.7	64	199	12.1
6	9	197	5.7	35	214	10.4	74	220	9.0	22	210	9.6
7	3	210	13.5	44	224	9.4	163	224	7.9	20	217	14.7
8	2	207	24.7	32	228	8.4	190	226	8.3	25	222	11.4
9	0			5	227	10.4	32	229	7.7	2	233	0.0
10	0			1	252		1	226		0		
11	0			0			1	235		0		
12	0			0			0			0		
13+	0			0			0			0		

Table 4. Significance levels of tests for differences in Pacific herring length (by fishery, age and fishery*age interaction) (ANOVA) and age-class composition (contingency table chi-square test) between the purse sac roe and various other commercial herring harvests, Prince William Sound, 1984-1987.

Year	PS Sac roe vs	ANOVA Model: Length = Fishery + Age + Fishery*Age						Age-Class Composition Comparisons (Contingency table chi-square test)		
		Fishery[a]	Age		Fishery * Age					
		P > F	P > F	df[b]	P > F	df[c]	df[d]	Chi-Square	P > Chi-Square	df
1984	PS Bait & Food	<0.0001	<0.0001	5	<0.0001	5	733	43.2	<0.0001	3
	GN Sac roe							570.0	<0.0001	5
	PS Pound	0.0808	<0.0001	6	0.0403	6	952	8.8	0.1175	5
1985	PS Bait & Food	<0.0001	<0.0001	6	<0.0001	6	1,707	201.3	<0.0001	6
	GN Sac roe							169.3	<0.0001	6
	PS Pound	0.3425	<0.0001	8	0.0780	8	2,191	77.0	<0.0001	6
1986	PS Bait & Food	<0.0001	<0.0001	8	<0.0001	8	3,405	1,050.2	<0.0001	7
	GN Sac roe							295.1	<0.0001	6
	PS Pound	<0.0001	<0.0001	7	0.9428	7	1,929	53.0	<0.0001	7
1987	PS Bait & Food	<0.0001	<0.0001	7	<0.0001	7	2,911	604.6	<0.0001	7
	GN Sac roe							348.4	<0.0001	6
	PS Pound	0.0003	<0.0001	8	<0.0001	8	3,484	1,099.8	<0.0001	8

[a] Degrees of freedom of the fishery effect for all ANOVAs = 1.

[b] Degrees of freedom of the age effect.

[c] Degrees of freedom of the fishery*age effect.

[d] Degrees of freedom of the mean square error term.

Table 5. LSMEAN length at age comparisons between the purse seine (PS) sac roe and the purse seine bait and food and the purse seine pound harvest samples, Prince William Sound, 1984.

	PS Sac Roe vs PS Bait & Food			PS Sac Roe vs PS Pound		
Age	Sac Roe LSMEANS	Bait & Food LSMEANS	P > |t|[a]	Sac Roe LSMEANS	Pound LSMEANS	P > |t|[a]
1						
2						
3	177.6	177.4	0.8550	177.6	178.5	0.5352
4	192.4	188.2	0.0003	192.4	188.5	0.0002
5	204.0	192.7	<0.0001	204.0	198.8	0.0060
6	213.9	197.4	0.0118	213.9	210.4	0.2176
7	224.0	210.0	0.0017	224.0	217.1	0.0163
8	227.9	206.5	<0.0001	227.9	222.2	0.0468
9				227.0	233.0	0.5014
10						
11						
12						
13+						

[a] The Bonferroni inequality (SAS 1985) was used to set the comparisonwise error rate (CER). CER = α/C, where α = 0.1 and C = number of simultaneous comparisons being made.

Table 6. Median length at age comparisons (Mann-Whitney-Wilcoxon test) between the purse seine (PS) and gill net (GN) sac roe harvest samples, Prince William Sound, 1984-1987.

	1984 PS Sac Roe vs GN Sac Roe			1985 PS Sac Roe vs GN Sac Roe			1986 PS Sac Roe vs GN Sac Roe			1987 PS Sac Roe vs GN Sac Roe		
Age	PS median	GN median	P > |z|[a]	PS median	GN median	P > |z|[a]	PS median	GN median	P > |z|[a]	PS median	GN median	P > |z|[a]
1												
2												
3							185.0	182.5	0.7372			
4	192.0	223.0	<0.0001	204.0	217.0	<0.0001	198.0	202.5	0.1159			
5	204.0	217.0	<0.0001	212.0	221.0	<0.0001	208.0	215.0	0.0507	206.0	218.5	<0.0001
6	217.0	221.0	0.0101	215.0	226.0	<0.0001	215.0	213.0	<0.0001	214.0	219.0	<0.0001
7	225.0	224.0	0.3452	226.5	229.5	0.0048	221.0	217.0	0.0000	221.0	223.5	0.0032
8	228.5	225.0	0.1101	234.0	234.0	0.7969	229.0	222.0	0.0004	230.0	227.0	0.3226
9	226.0	228.0	0.5937	234.0	235.0	0.2445	231.0	224.0	0.0242	230.5	233.0	0.3424
10				232.0	237.5	0.3242	234.0	227.0	<0.0001	238.0	236.0	0.3977
11				225.5	230.5	0.4414	231.5	228.0	0.4826	238.0	238.0	1.0000
12										250.0	241.0	0.0550
13+												

[a] The Bonferroni inequality (SAS 1985) was used to set the comparison-wise error rate (CER). CER = α/C, where α = 0.1 and C = number of simultaneous comparisons being made.

Table 7. Pacific herring commercial spawn-on-kelp harvest summary, Prince William Sound, 1984-1987.

Harvest Year	Natural Spawn-On-Kelp					Pound Spawn-On-Kelp				
	Harvest (tonnes)	Estimated Value (X $1,000)	Effort (number of divers)	Duration (hours)	Period	Harvest (tonnes)	Estimated Value (X $1,000)	Effort (number of pounds)	Duration (days)	Period
1984	0.0	0.0	0	0	[a]	24.2	270.0	45	14	04/24 - 05/08
1985	18.7	36.6	107	20	05/06 & 05/08	36.5	570.0	59	12	04/25 - 05/07
1986	42.9	160.0	29	94	04/30 - 05/04	64.4	1,150.0	82	6	04/27 - 05/03
1987	79.9	284.0	98	48	04/15 - 04/17	54.7	1,800.0	111	11	04/10 - 04/21

[a] The natural spawn-on-kelp fishery was not opened in 1984 due to the lack of a marketable quality product.

Table 8. Sample size, mean length, and standard deviation at age of the Pacific herring sampled from the various commercial harvests, Prince William Sound, 1985.

Age	Purse Seine Bait & Food			Purse Seine Sac Roe			Gill Net Sac Roe			Purse Seine Pound		
	n	Mean Length (mm)	Standard Deviation	n	Mean Length (mm)	Standard Deviation	n	Mean Length (mm)	Standard Deviation	n	Mean Length (mm)	Standard Deviation
1	3	180	7.0	0			0			0		
2	1	151		4	159	4.5	0			3	165	15.2
3	70	173	10.6	37	190	10.6	0			86	184	16.4
4	261	184	10.7	244	204	11.0	19	217	11.6	321	203	10.6
5	164	186	10.8	401	211	11.1	141	220	7.2	402	210	9.7
6	75	190	9.4	155	217	9.2	98	225	7.6	114	219	13.6
7	21	200	9.5	74	225	8.3	49	231	9.2	25	222	12.1
8	8	197	9.5	50	232	10.6	54	234	7.1	46	233	9.6
9	8	204	11.6	154	233	11.2	134	235	8.9	90	233	9.8
10	0			6	230	6.9	12	232	15.4	1	235	
11	0			2	226	0.7	2	231	6.4	2	242	15.6
12	0			0			0			0		
13+	0			0			0			0		

Table 9. LSMEAN length at age comparisons between the purse seine (PS) sac roe and the purse seine bait and food and the purse seine pound harvest samples, Prince William Sound, 1985.

	PS Sac Roe vs PS Bait & Food			PS Sac Roe vs PS Pound		
Age	Sac Roe LSMEANS	Bait & Food LSMEANS	P > |t|[a]	Sac Roe LSMEANS	Pound LSMEANS	P > |t|[a]
1						
2				159.0	165.3	0.4468
3	189.6	172.5	<0.0001	189.6	183.6	0.0054
4	203.8	184.4	<0.0001	203.8	203.0	0.4336
5	211.2	186.4	<0.0001	211.2	210.3	0.2220
6	217.0	189.8	<0.0001	217.0	218.6	0.2484
7	225.5	199.9	<0.0001	225.5	221.8	0.1424
8	232.2	196.8	<0.0001	232.2	232.9	0.7562
9	232.9	204.1	<0.0001	232.9	232.9	0.9920
10						
11				225.5	242.0	0.1302
12						
13+						

[a] The Bonferroni inequality (SAS 1985) was used to set the comparisonwise error rate (CER). CER = α/C, where α = 0.1 and C = number of simultaneous comparisons being made.

Table 10. Sample size, mean length, and standard deviation at age of the Pacific herring samples obtained from the various commercial harvests, Prince William Sound, 1986.

Age	Purse Seine Bait & Food			Purse Seine Sac Roe			Gillnet Sac Roe			Purse Seine Pound		
	n	Mean Length (mm)	Standard Deviation	n	Mean Length (mm)	Standard Deviation	n	Mean Length (mm)	Standard Deviation	n	Mean Length (mm)	Standard Deviation
1	0			0			0			0		
2	323	126		1	152		0			0		
3	533	155	17.8	57	184	13.1	2	183	0.7	43	181	9.9
4	720	170	13.7	88	199	9.2	14	203	10.5	95	193	12.3
5	453	183	12.8	407	208	7.7	395	209	9.4	234	203	9.2
6	253	182	15.4	453	215	8.4	825	213	8.7	208	210	9.0
7	128	186	10.5	108	221	9.9	285	216	8.8	39	217	11.0
8	37	190	9.9	42	226	10.1	125	221	9.5	4	221	2.1
9	17	196	8.0	25	229	9.6	104	224	10.1	11	226	5.0
10	2	197	16.3	95	234	8.4	207	227	8.6	36	230	9.2
11	2	199	8.5	3	234	7.8	11	229	7.4	0		
12	2	166	5.7	1	213		1	215		0		
13+	5	179	18.4	0			2	227	0.7	0		

Table 11. LSMEAN length at age comparisons between the purse seine (PS) sac roe and the purse seine bait and food and the purse seine pound harvest samples, Prince William Sound, 1986.

	PS Sac Roe vs PS Bait & Food			PS Sac Roe vs PS Pound		
Age	Sac Roe LSMEANS	Bait & Food LSMEANS	P > |t|[a]	Sac Roe LSMEANS	Pound LSMEANS	P > |t|[a]
1						
2						
3	184.2	155.2	<0.0001	184.2	181.2	0.0929
4	199.4	170.2	<0.0001	199.4	193.2	<0.0001
5	207.9	183.0	<0.0001	207.9	203.1	<0.0001
6	215.0	182.3	<0.0001	215.0	210.3	<0.0001
7	221.4	186.0	<0.0001	221.4	216.7	0.0057
8	225.8	189.9	<0.0001	225.8	221.3	0.3348
9	228.5	196.5	<0.0001	228.5	225.5	0.3653
10	234.2	196.5	<0.0001	234.2	229.7	0.0113
11	234.0	199.0	0.0027			
12						
13+						

[a] The Bonferroni inequality (SAS 1985) was used to set the comparisonwise error rate (CER). CER = α/C, where α = 0.1 and C = number of simultaneous comparisons being made.

Table 12. Significance levels and chi-square values for age group (ages 2-4, 5-7 and > 8 years old) comparisons between ADF&G beach seine samples, Prince William Sound, April 12-17, 1986.

Sample Location	Prob. > Chi-Square[a]				Chi-Square Statistic			
	North Shore	Port Fidalgo	Port Chalmers	Unakwik Point	North Shore	Port Fidalgo	Port Chalmers	Unakwik Point
North Shore	-	<0.0001	0.0067	0.0268	-	430.2	10.0	7.2
Port Fidalgo		-	<0.0001	<0.0001		-	189.0	283.5
Port Chalmers			-	0.0753			-	5.2
Unakwik Point				-				-

[a] The Bonferroni inequality (SAS 1985) was used to set the comparison-wise error rate (CER). CER = α/C, where α 0.1 and C = number of a simultaneous comparisons being made.

Table 13. Sample size, mean length, and standard deviation at age of the Pacific herring samples obtained from the various commercial harvests, Prince William Sound, 1987.

Age	Purse Seine Bait & Food			Purse Seine Sac Roe			Gillnet Sac Roe			Purse Seine Pound		
	n	Mean Length (mm)	Standard Deviation	n	Mean Length (mm)	Standard Deviation	n	Mean Length (mm)	Standard Deviation	n	Mean Length (mm)	Standard Deviation
1	0			0			0			0		
2	65	146	8.9	1	171		0			9	152	12.1
3	271	163	12.2	266	182	8.0	0			1,180	170	9.1
4	314	180	12.7	139	198	9.4	0			144	181	15.2
5	306	187	10.6	173	206	8.8	18	218	7.1	78	198	15.2
6	158	193	10.0	570	214	8.5	156	219	6.9	185	214	10.5
7	78	193	15.7	450	221	10.0	212	223	6.8	101	222	10.3
8	47	195	9.7	60	228	10.1	73	227	7.9	19	232	5.9
9	11	196	6.4	40	232	8.9	37	233	6.9	11	235	5.2
10	5	197	5.4	39	236	9.4	54	235	8.0	12	235	10.4
11	0			27	238	9.0	29	237	7.7	8	243	6.2
12	0			2	250	0.0	7	241	4.6	1	227	
13+	3	180	21.9	0			0			0		

Table 14. LSMEAN length at age comparisons between the purse seine (PS) sac roe and the purse seine bait and food and the purse seine pound harvest samples, Prince William Sound, 1987.

	PS Sac Roe vs PS Bait & Food			PS Sac Roe vs PS Pound		
Age	Sac Roe LSMEANS	Bait & Food LSMEANS	P > |t|[a]	Sac Roe LSMEANS	Pound LSMEANS	P > |t|[a]
1						
2						
3	182.2	163.3	<0.0001	182.2	169.9	<0.0001
4	197.5	180.2	<0.0001	197.5	181.1	<0.0001
5	206.0	187.5	<0.0001	206.0	198.4	<0.0001
6	214.2	193.5	<0.0001	214.2	214.5	0.7049
7	221.2	192.7	<0.0001	221.2	221.8	0.5729
8	227.6	194.6	<0.0001	227.6	232.0	0.0842
9	232.0	196.2	<0.0001	232.0	235.2	0.3324
10	236.3	197.0	<0.0001	236.3	234.8	0.6374
11				237.9	242.5	0.2386
12						
13+						

[a] The Bonferroni inequality (SAS 1985) was used to set the comparisonwise error rate (CER). CER = α/C, where α = 0.1 and C = number of simultaneous comparisons being made.

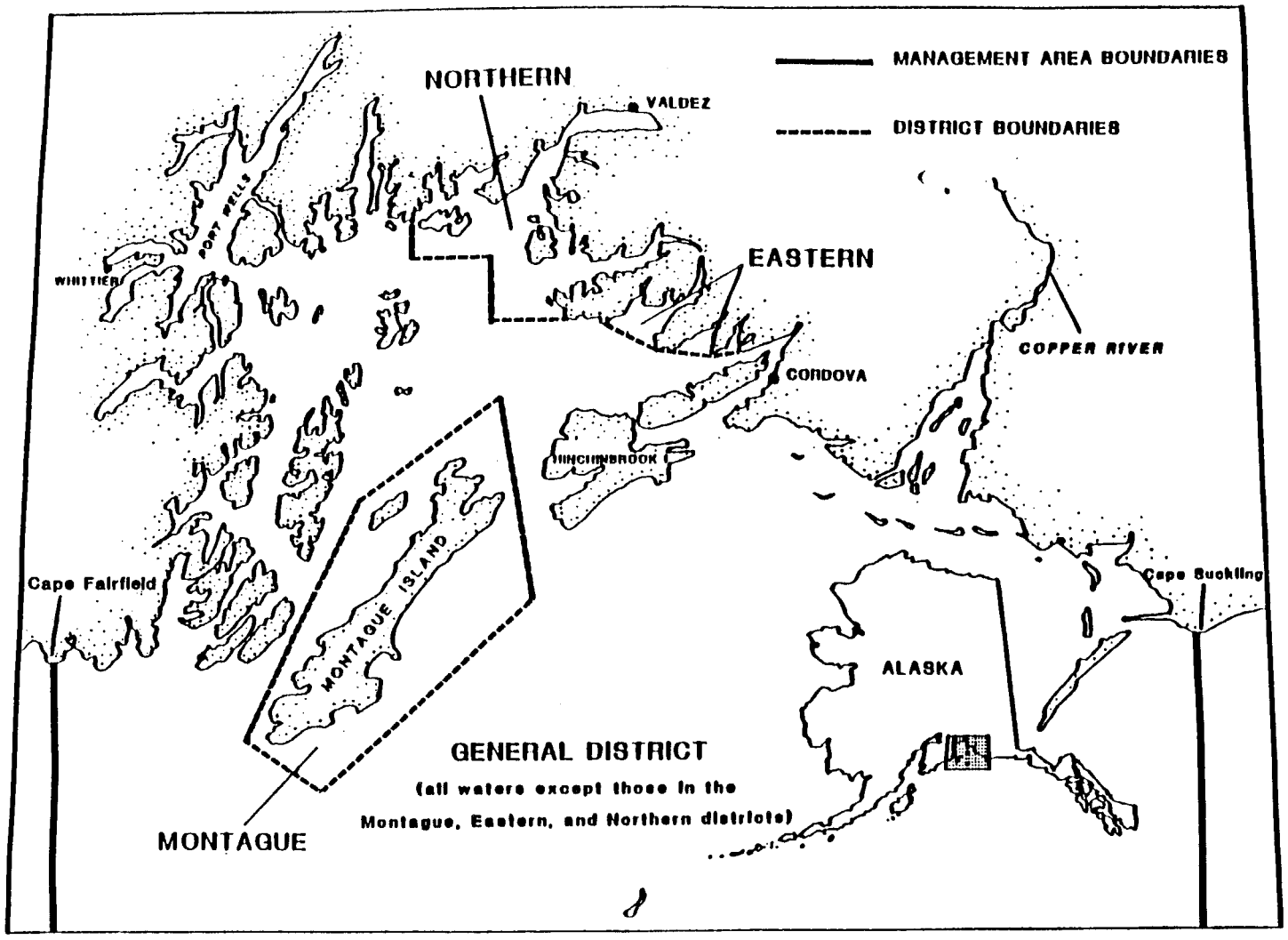

Figure 1. Prince William Sound herring management area and associated herring management districts.

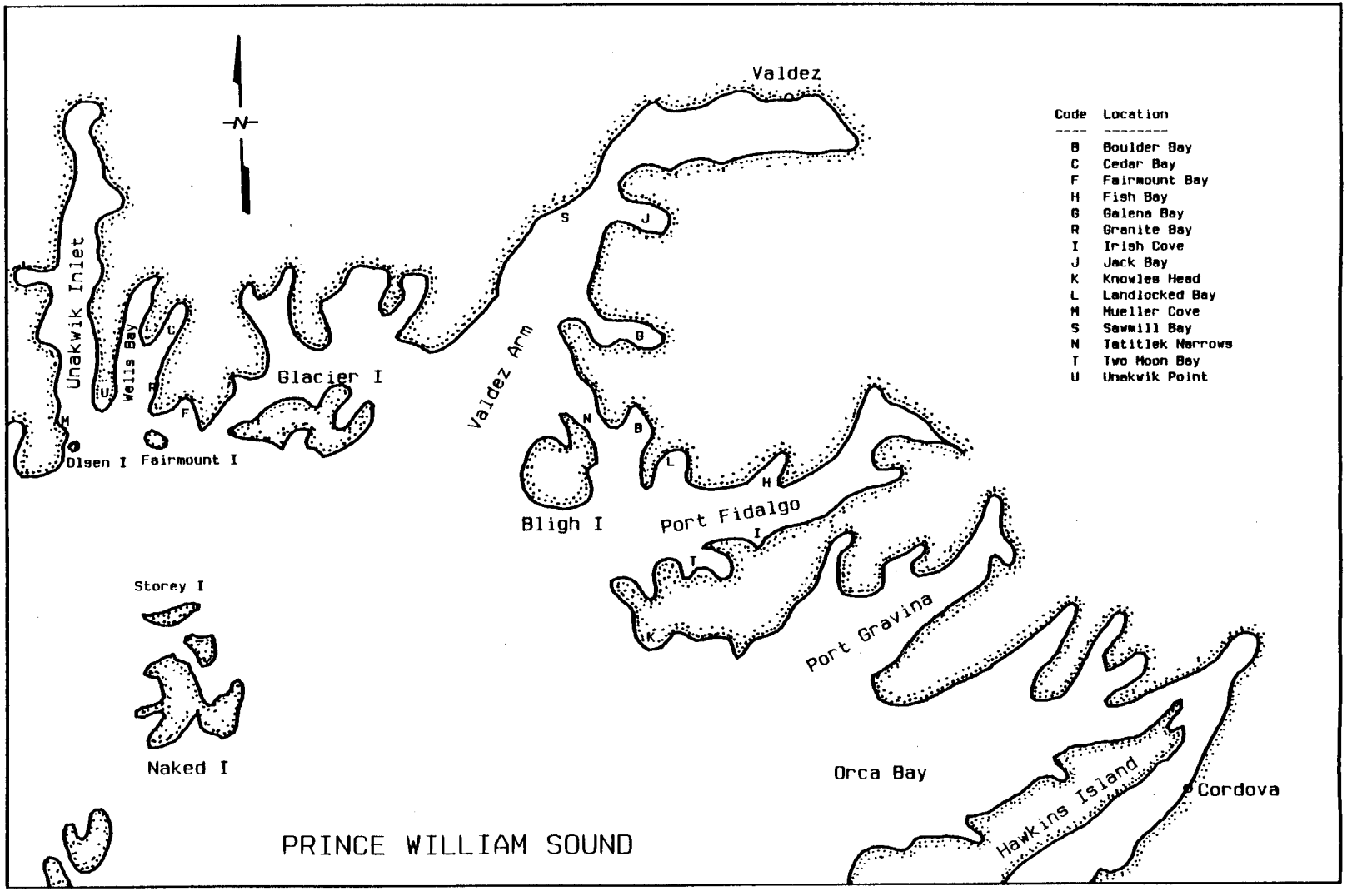

Figure 2. Northern, Eastern, and the northern portion of the General herring management districts, Prince William Sound herring management area.

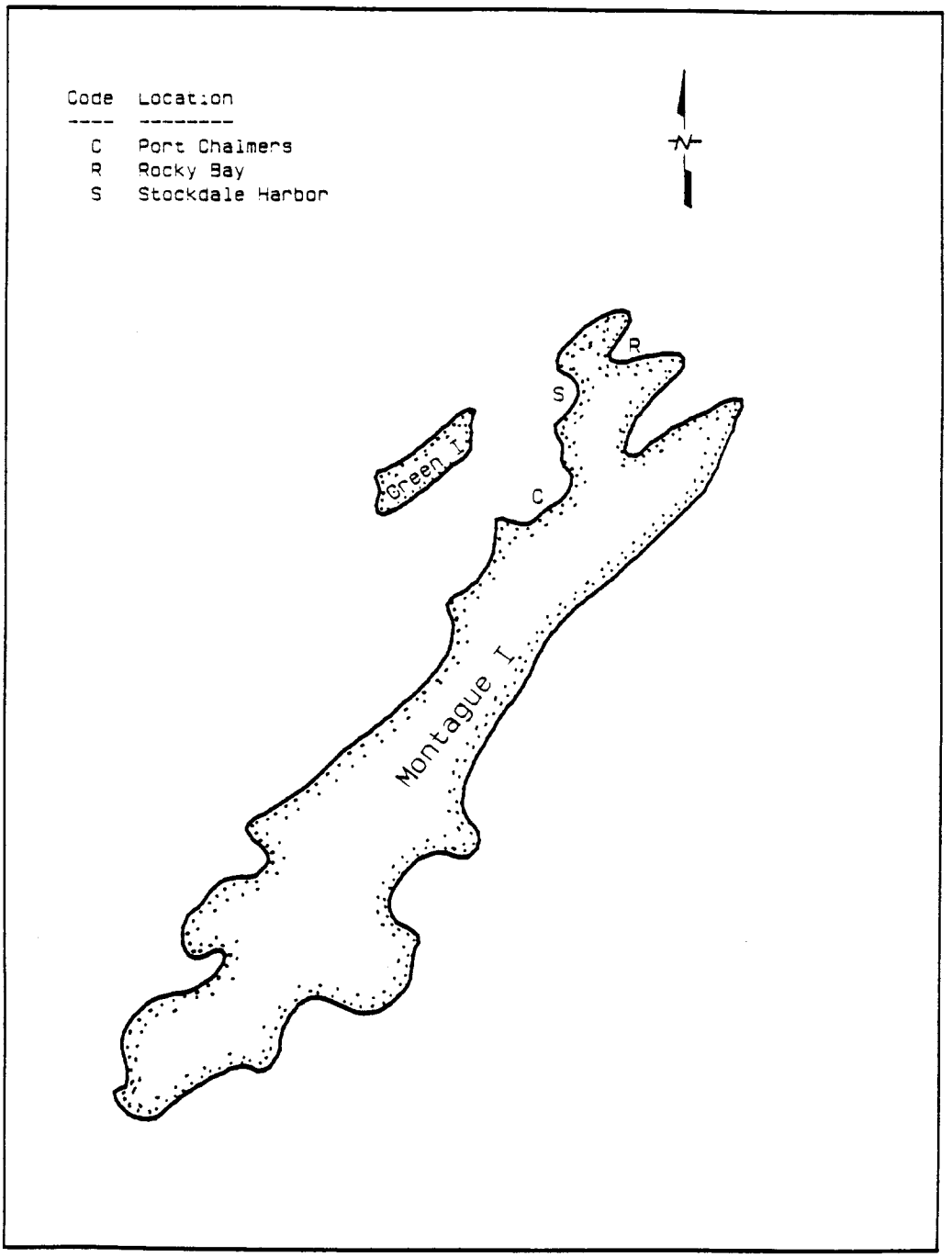

Figure 3. Montague and the southern portion of the General herring management districts, Prince William Sound herring management area.

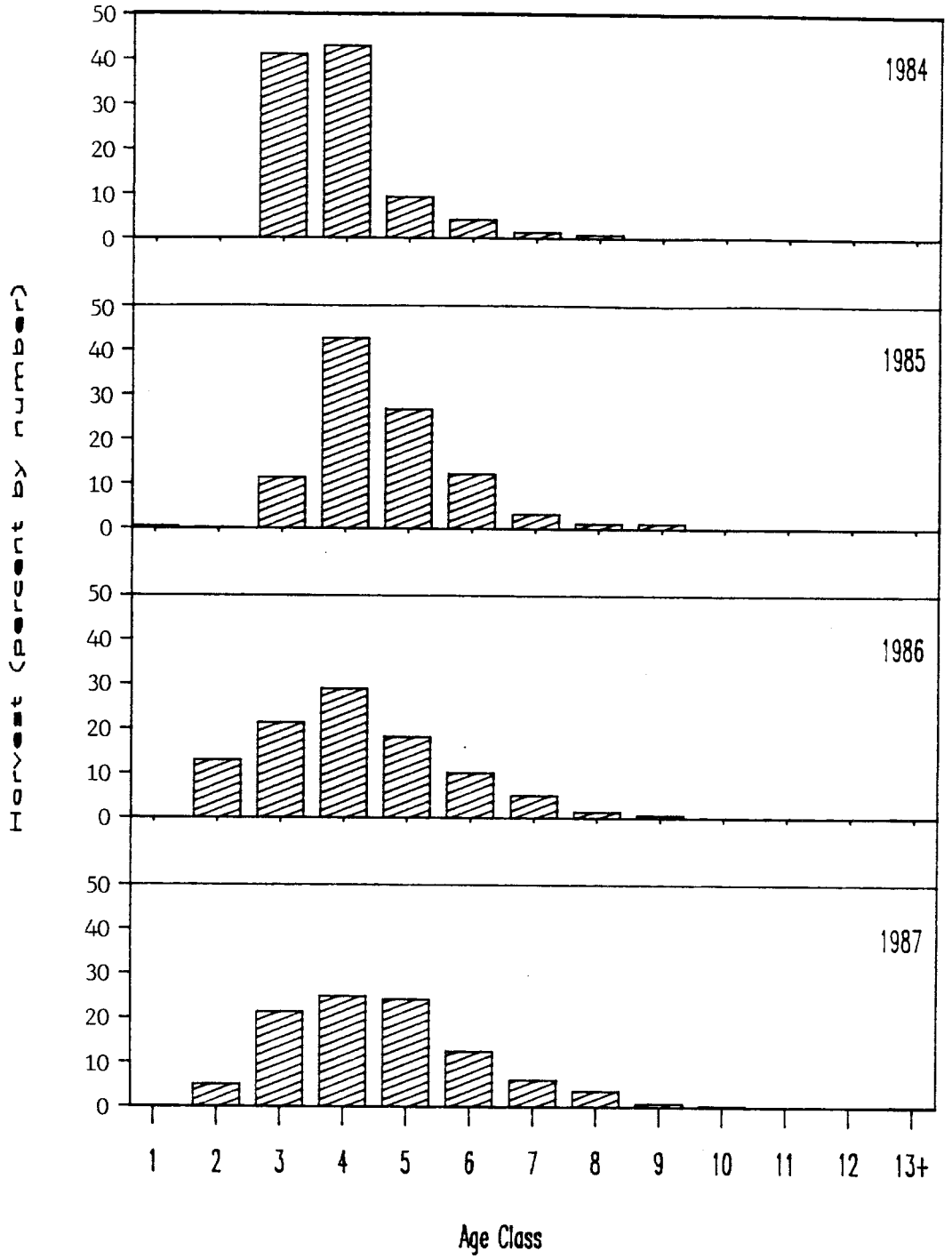

Figure 4. Age-class composition of the purse seine bait and food Pacific herring harvest, Prince William Sound, 1984 - 1987.

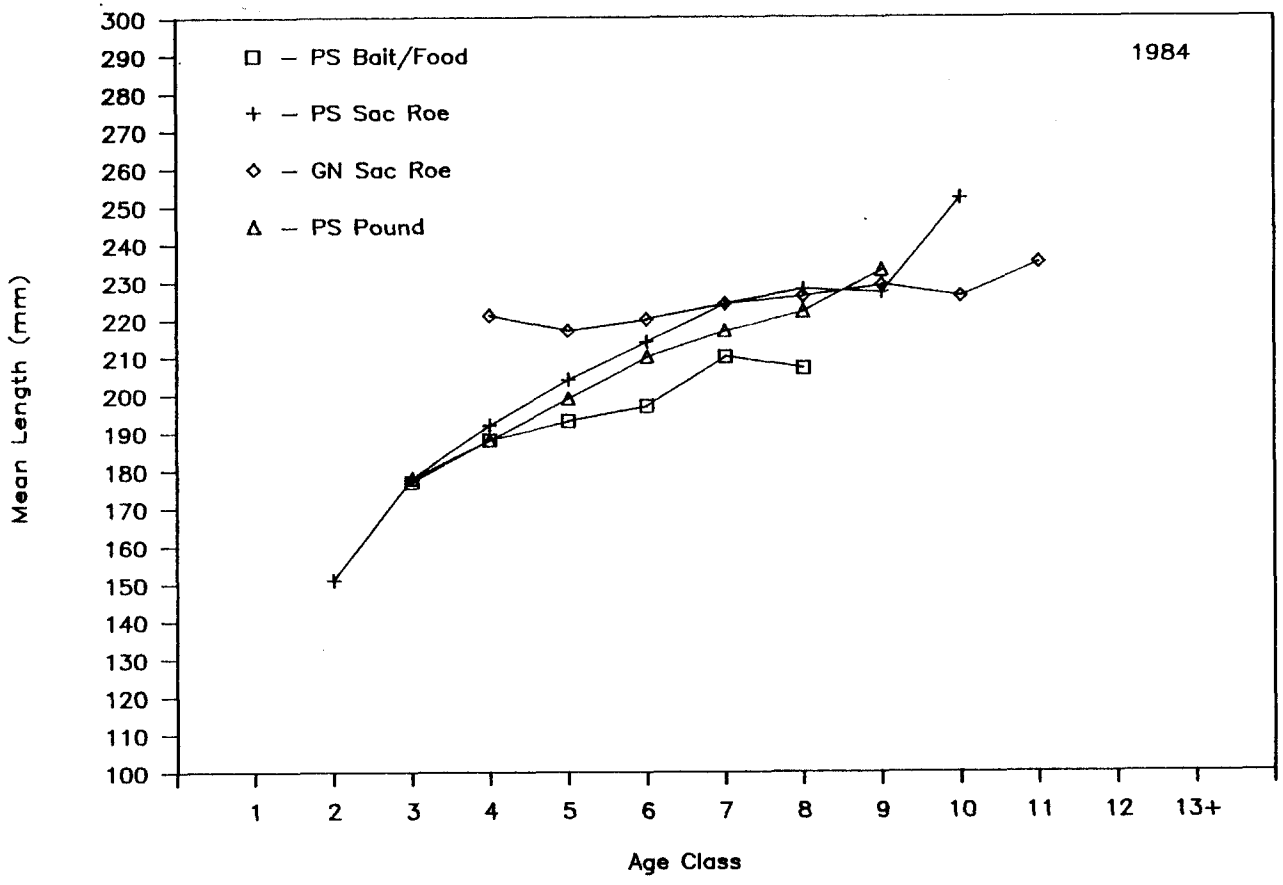

Figure 5. Mean length at age of Pacific herring sampled from the purse seine (PS) bait and food, purse seine sac roe and gill net (GN) sac roe harvests, and herring utilized in the purse seine pound spawn-on-kelp fishery, Prince William Sound, 1984.

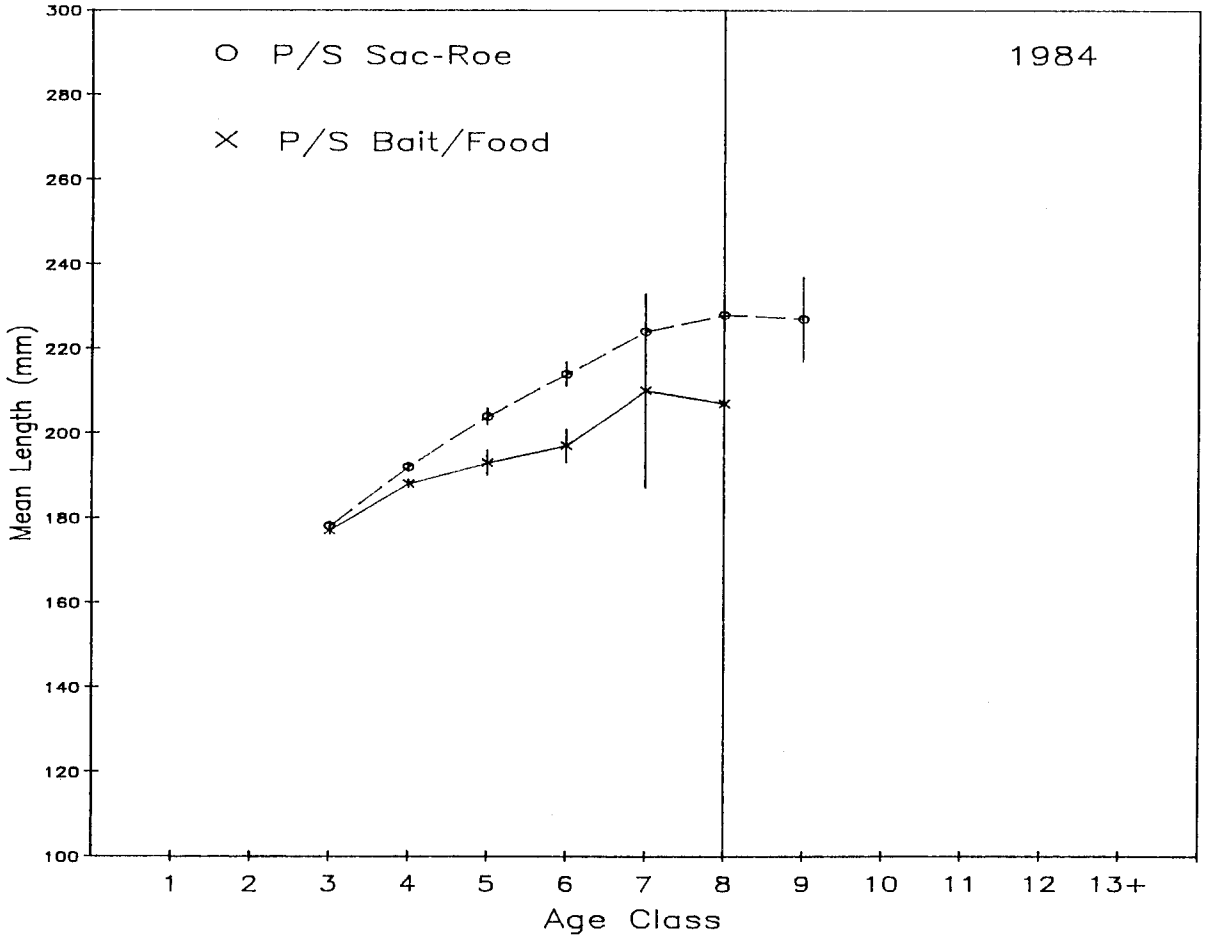

Figure 6. Mean length at age and the associated 90% confidence interval of Pacific herring sampled from the purse seine bait and food and sac roe harvests, Prince William Sound, 1984.

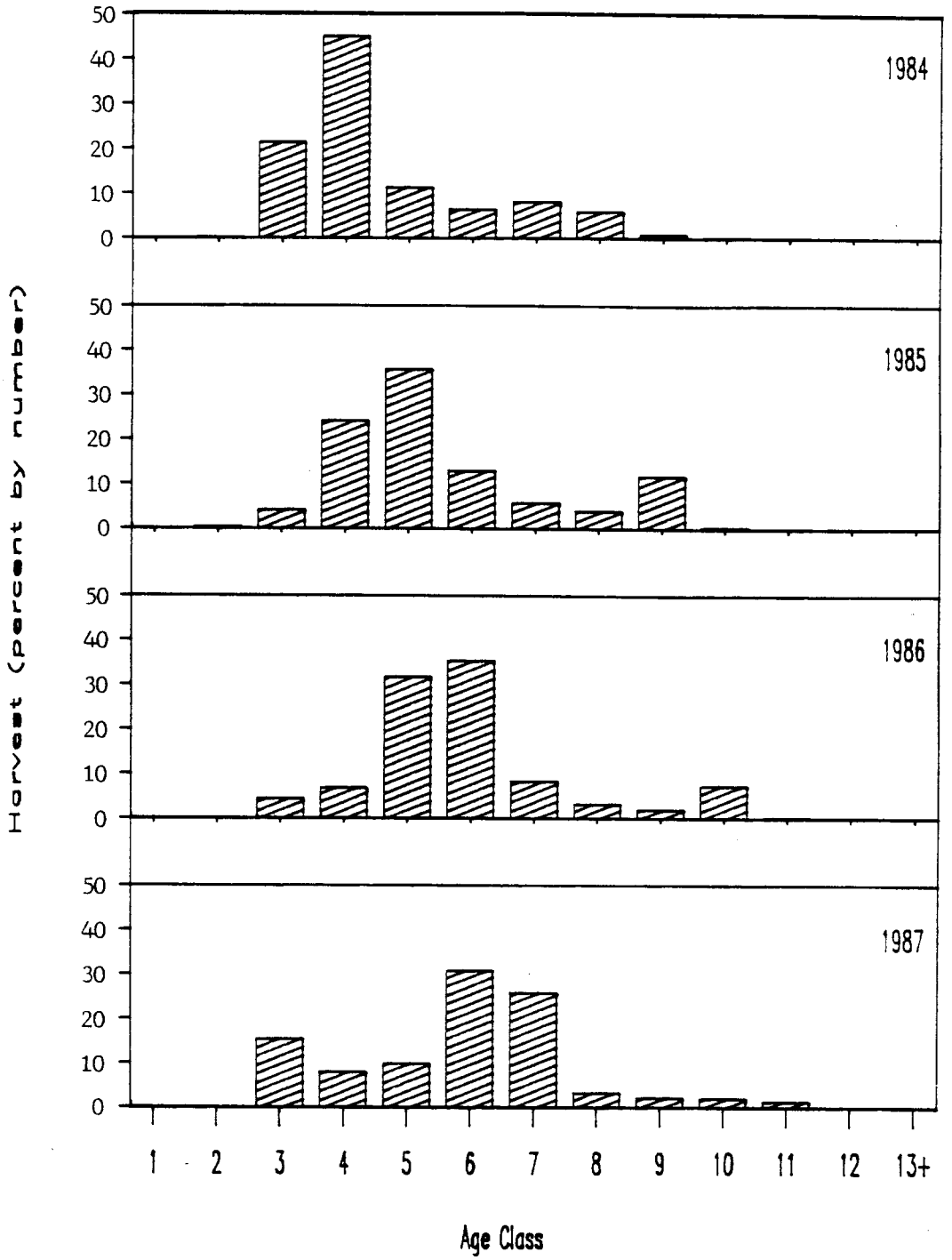

Figure 7. Age-class composition of the purse seine sac roe Pacific herring harvest, Prince William Sound, 1984 - 1987.

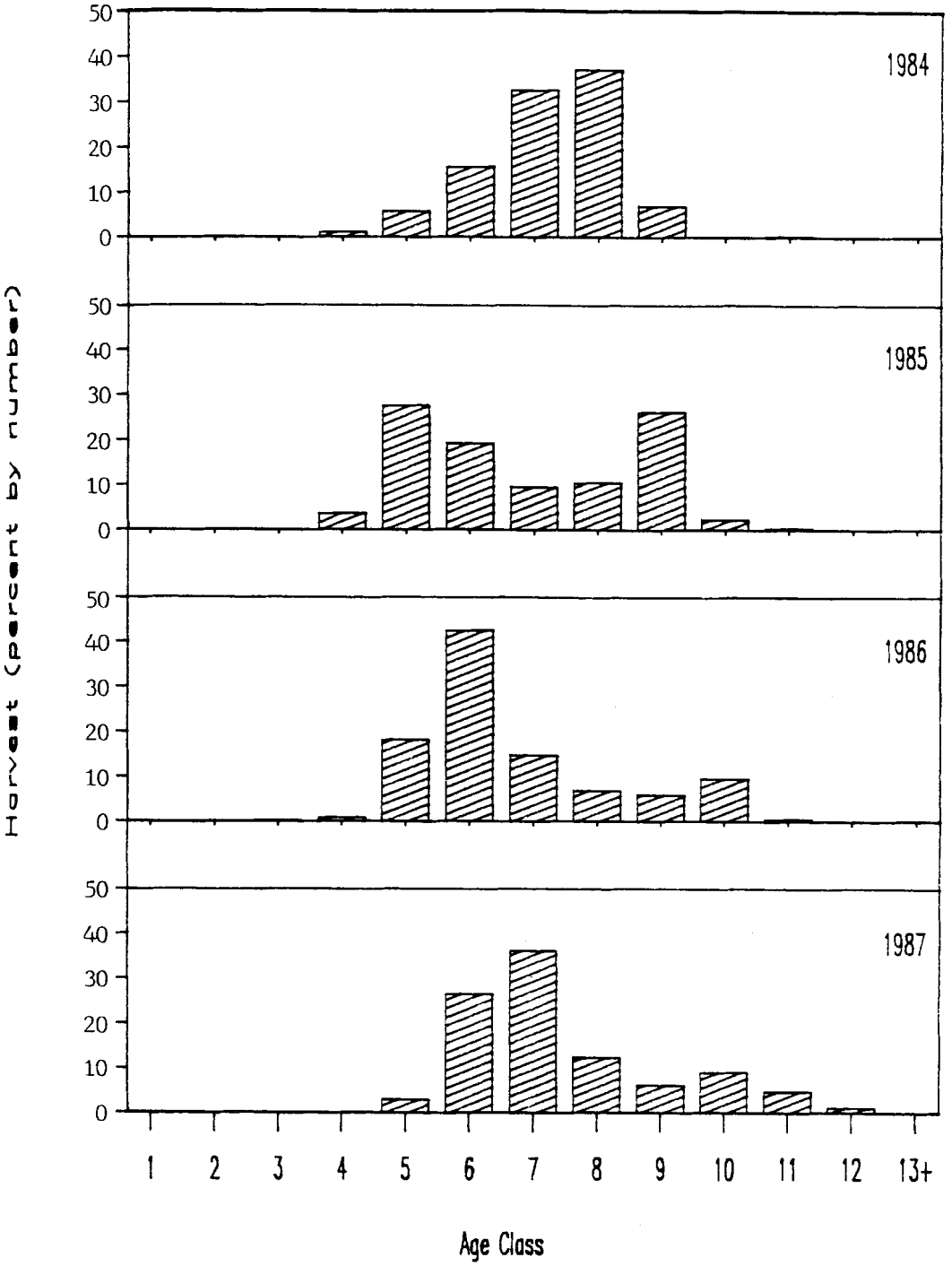

Figure 8. Age-class composition of the gill net sac roe Pacific herring harvest, Prince William Sound, 1984 - 1987.

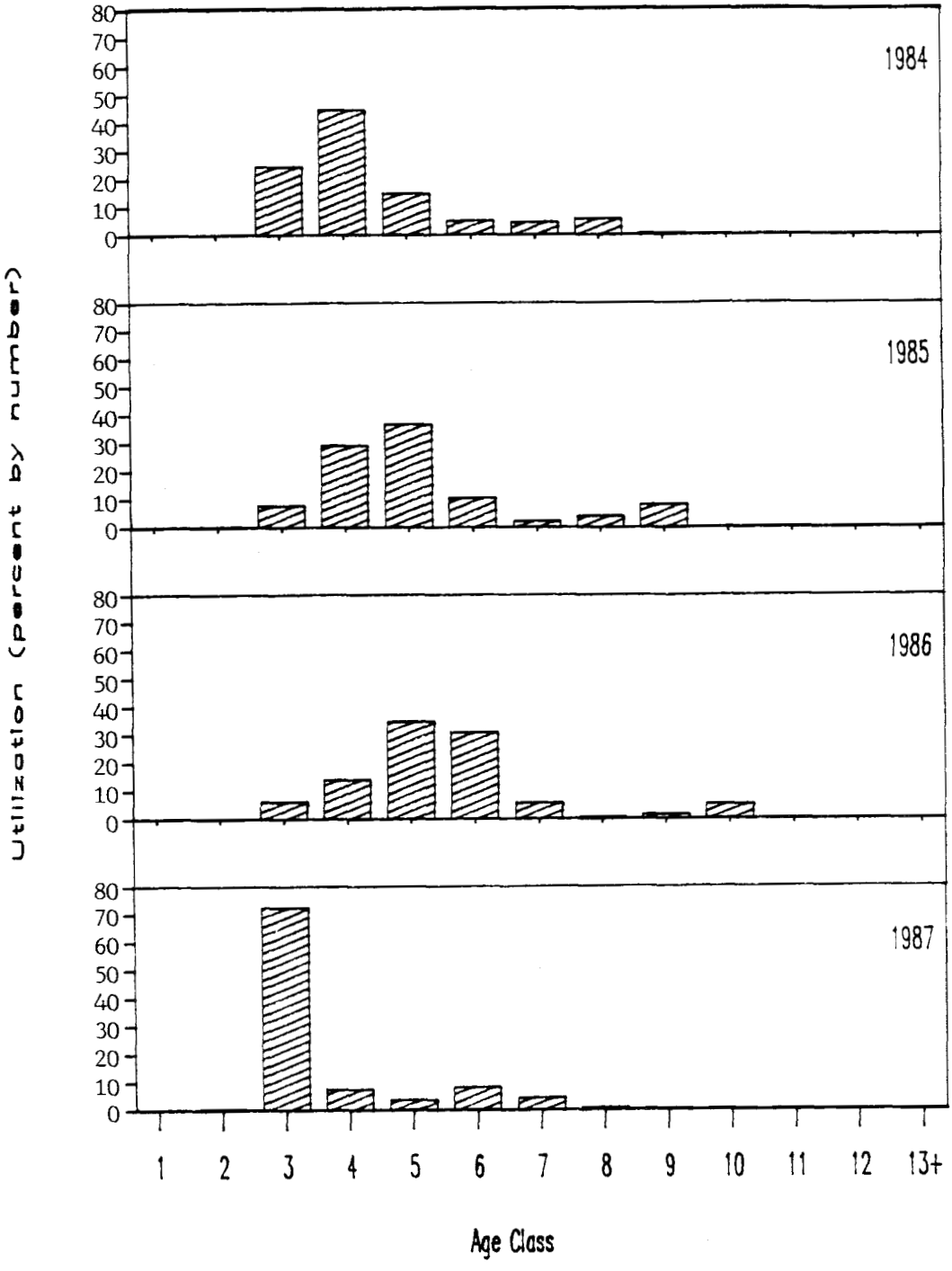

Figure 9. Age-class composition of the Pacific herring utilized in the pound spawn-on-kelp fishery, Prince William Sound, 1984 - 1987.

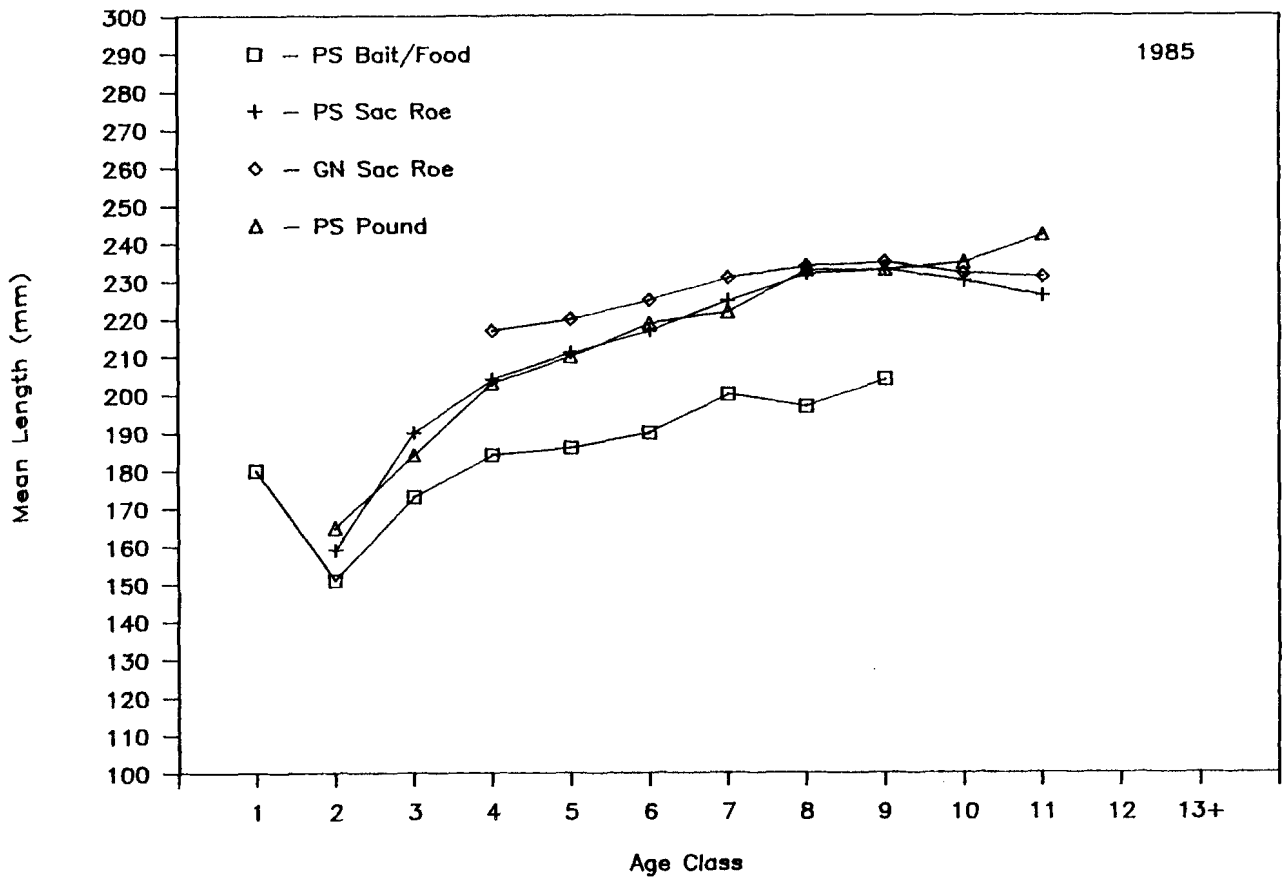

Figure 10. Mean length at age of Pacific herring sampled from the purse seine (PS) bait and food, purse seine sac roe and gill net (GN) sac roe harvests, and herring utilized in the purse seine pound spawn-on-kelp fishery, Prince William Sound, 1985.

Figure 11. Mean length at age and the associated 90% confidence interval of Pacific herring sampled from the purse seine bait and food and sac roe harvests, Prince William Sound, 1985.

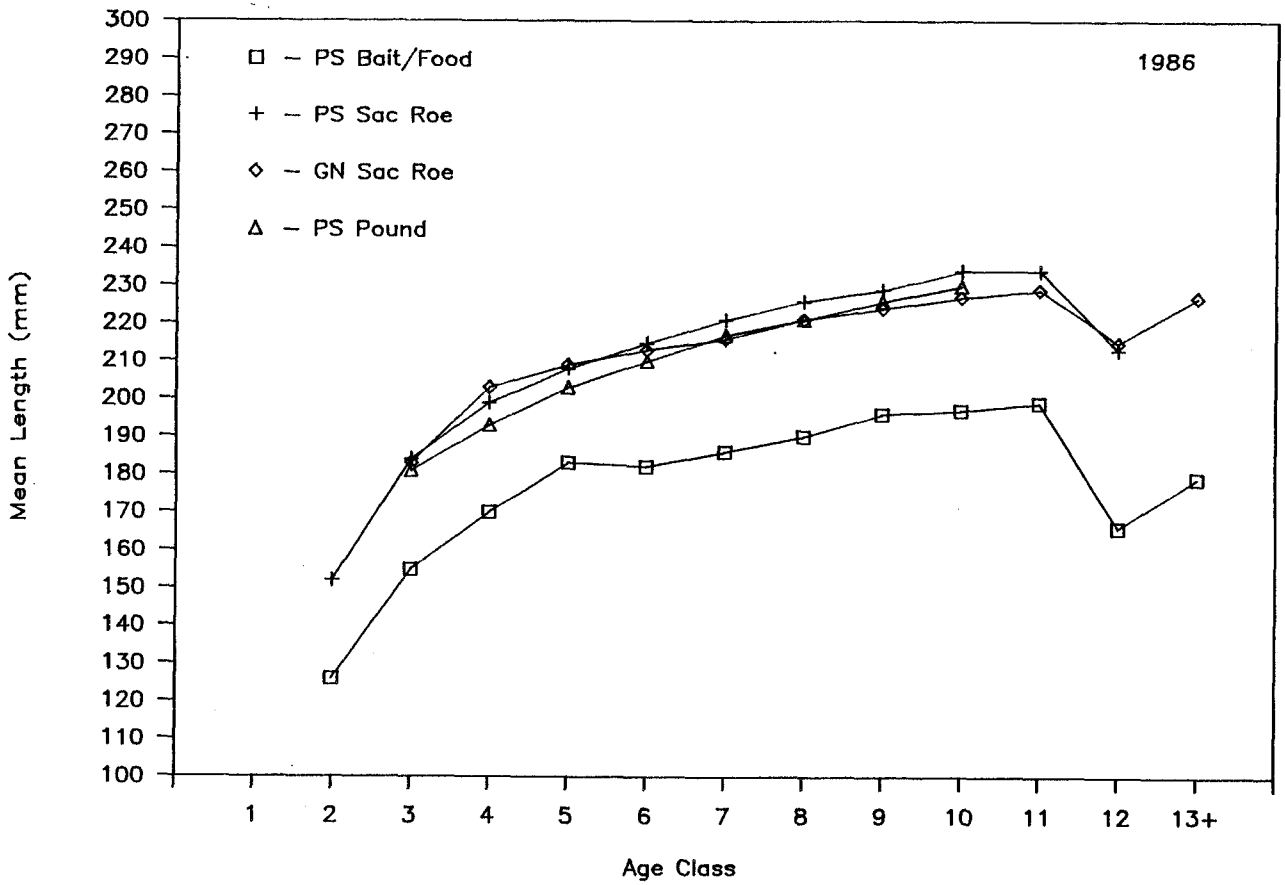

Figure 12. Mean length at age of Pacific herring sampled from the purse seine (PS) bait and food, purse seine sac roe and gill net (GN) sac roe harvests, and herring utilized in the purse seine pound spawn-on-kelp fishery, Prince William Sound, 1986.

Figure 13. Mean length at age and the associated 90% confidence interval of Pacific herring sampled from the purse seine bait and food and sac roe harvests, Prince William Sound, 1986.

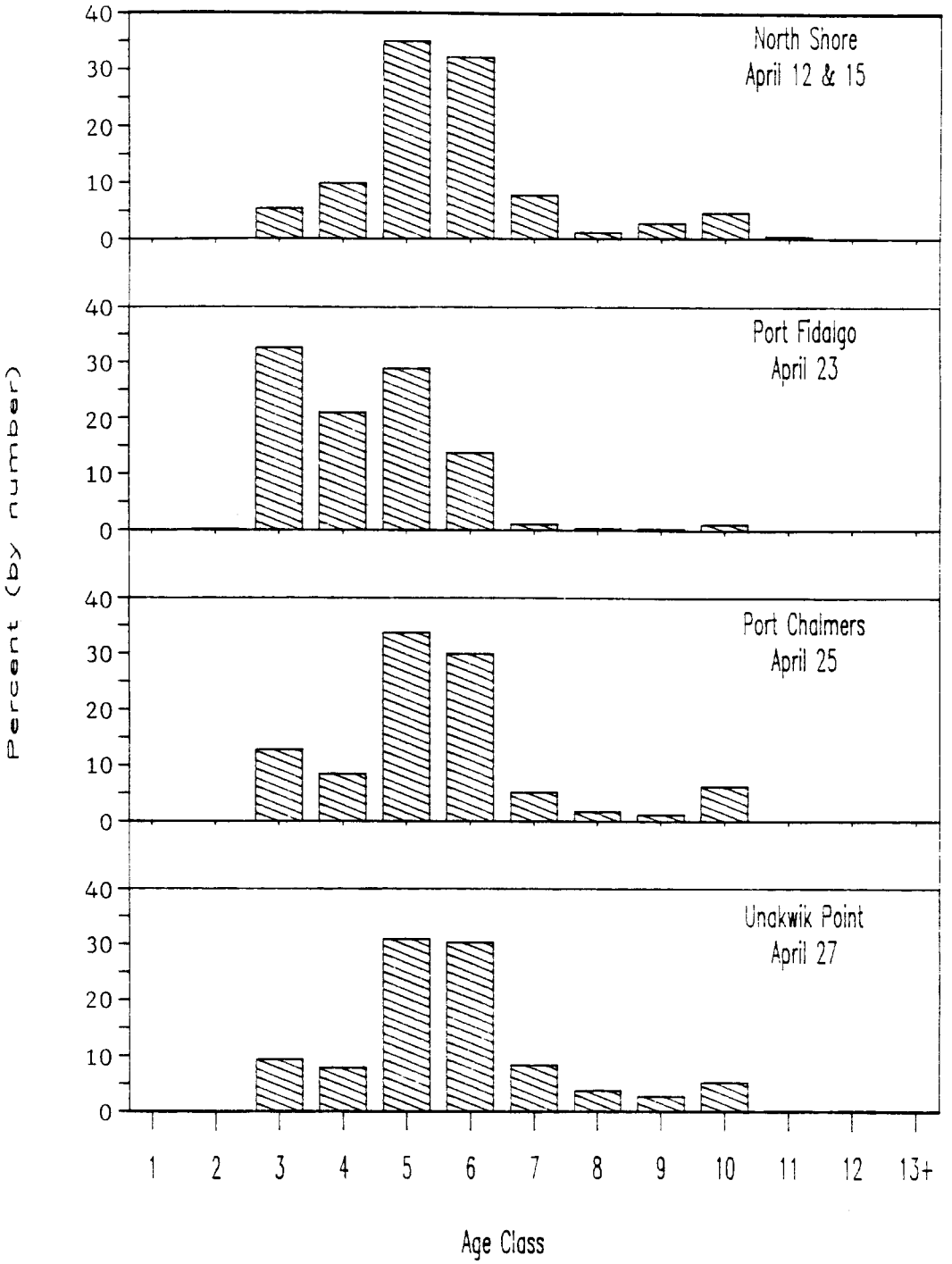

Figure 14. Age-class composition of Pacific herring captured by ADF&G test beach seines from the north shore (Olsen and Fairmont Islands), Port Fidalgo (Irish Cove and Fish Bay) Port Chalmers, and Unakwik Point, Prince William Sound, 1986.

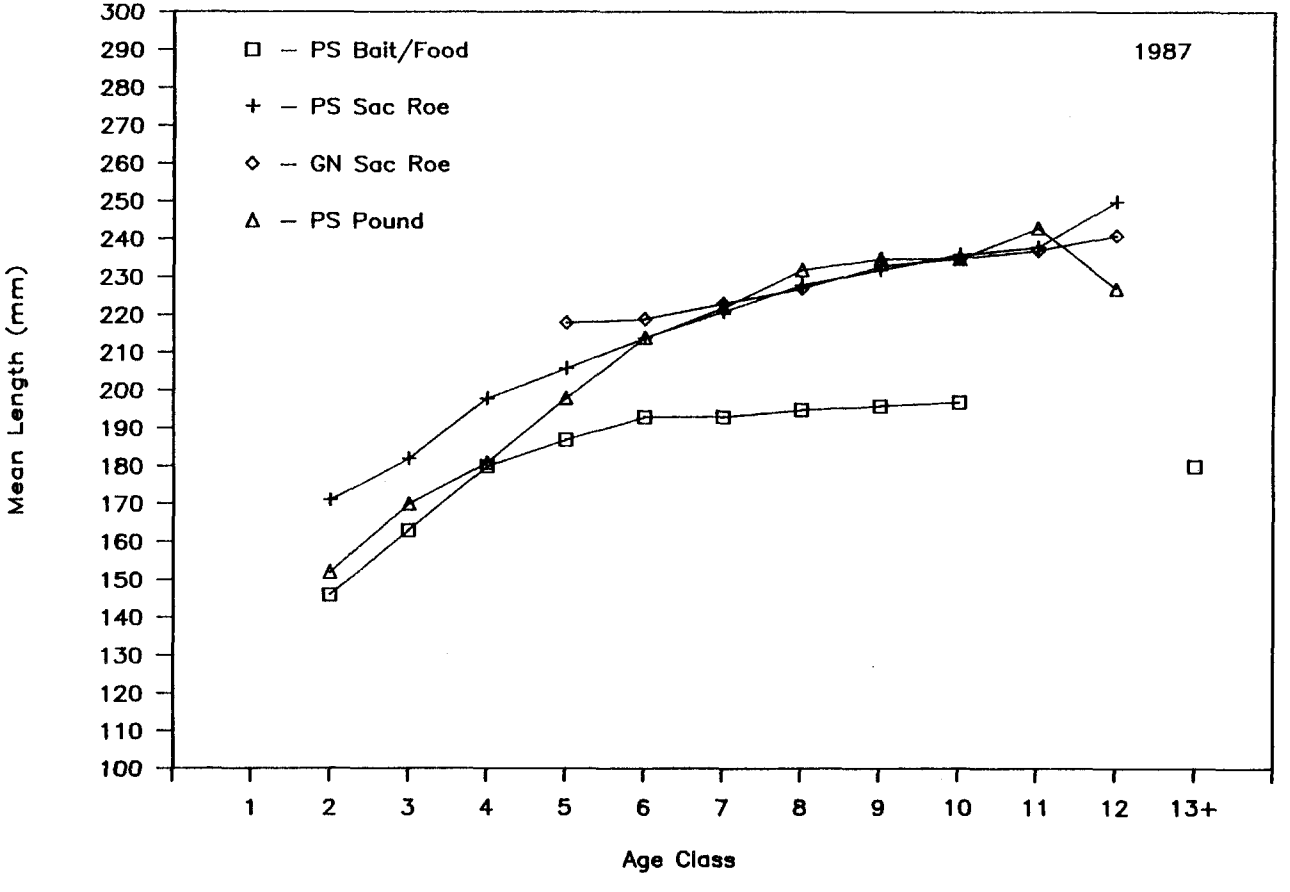

Figure 15. Mean length at age of Pacific herring sampled from the purse seine (PS) bait and food, purse seine sac roe and gill net (GN) sac roe harvests, and herring utilized in the purse seine pound spawn-on-kelp fishery, Prince William Sound, 1987.

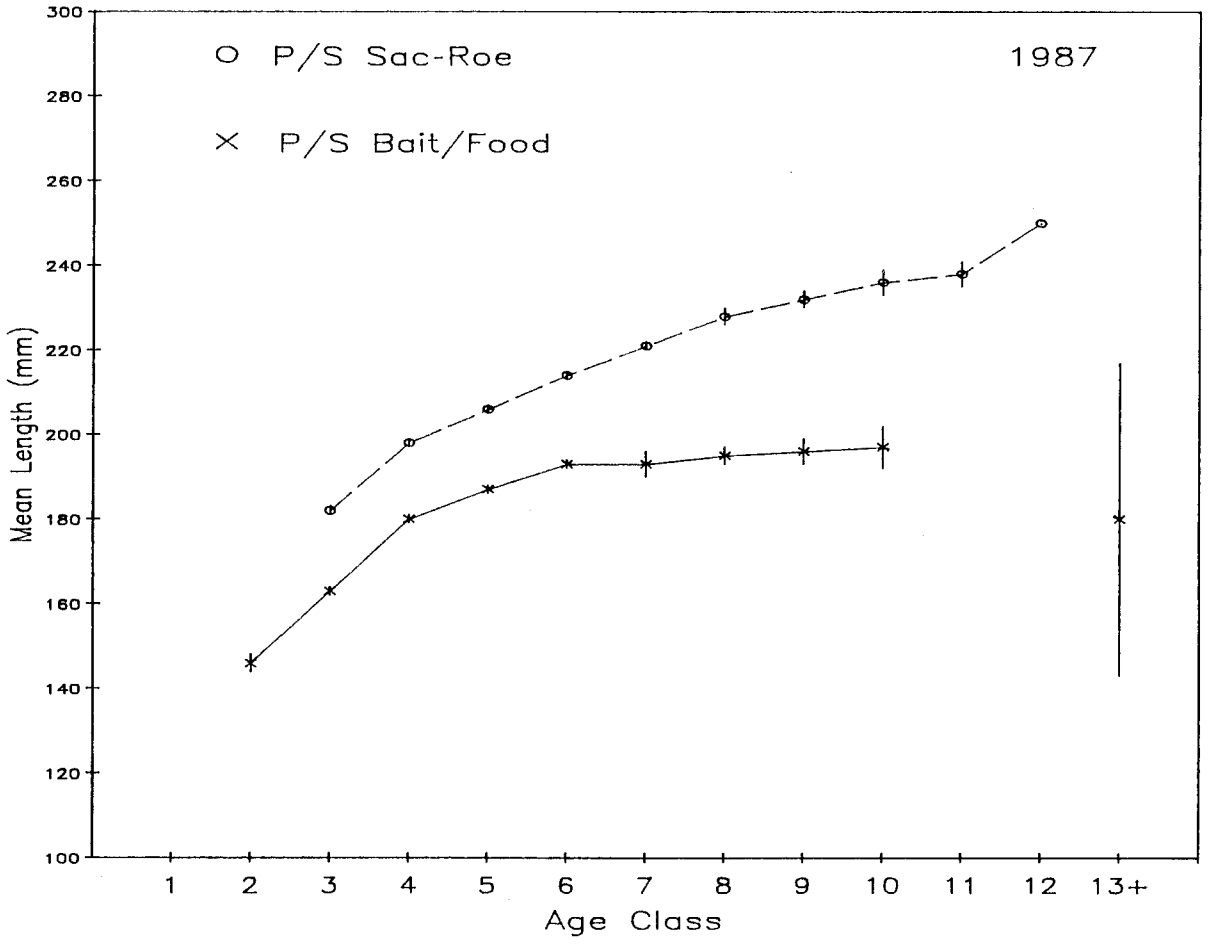

Figure 16. Mean length at age and the associated 90% confidence interval of Pacific herring sampled from the purse seine bait and food and sac roe harvests, Prince William Sound, 1987.

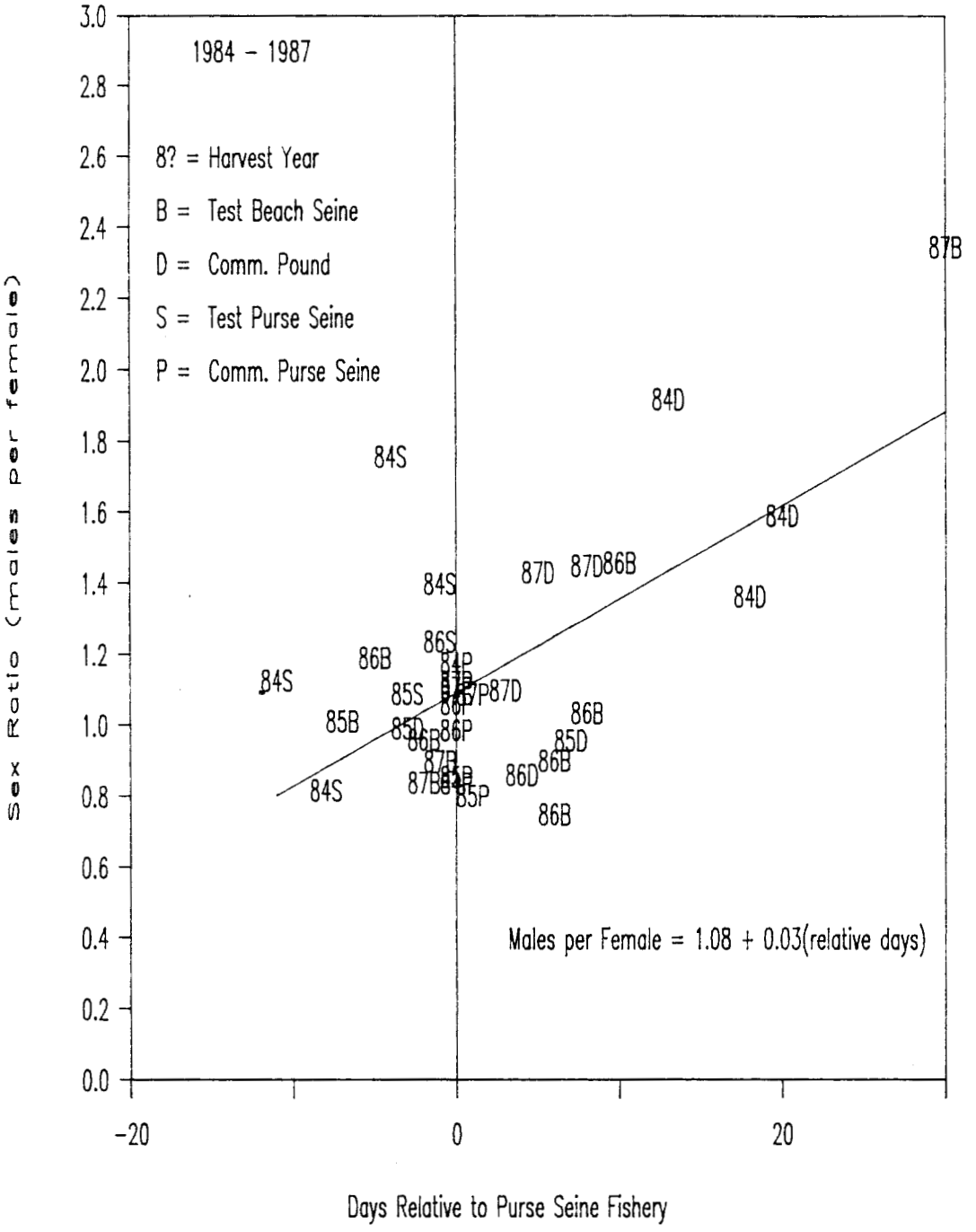

Figure 17. Pacific herring commercial and test sample sex ratios versus time relative to the initiation of the annual commercial purse seine sac roe fishery, Prince William Sound, 1984 - 1987.

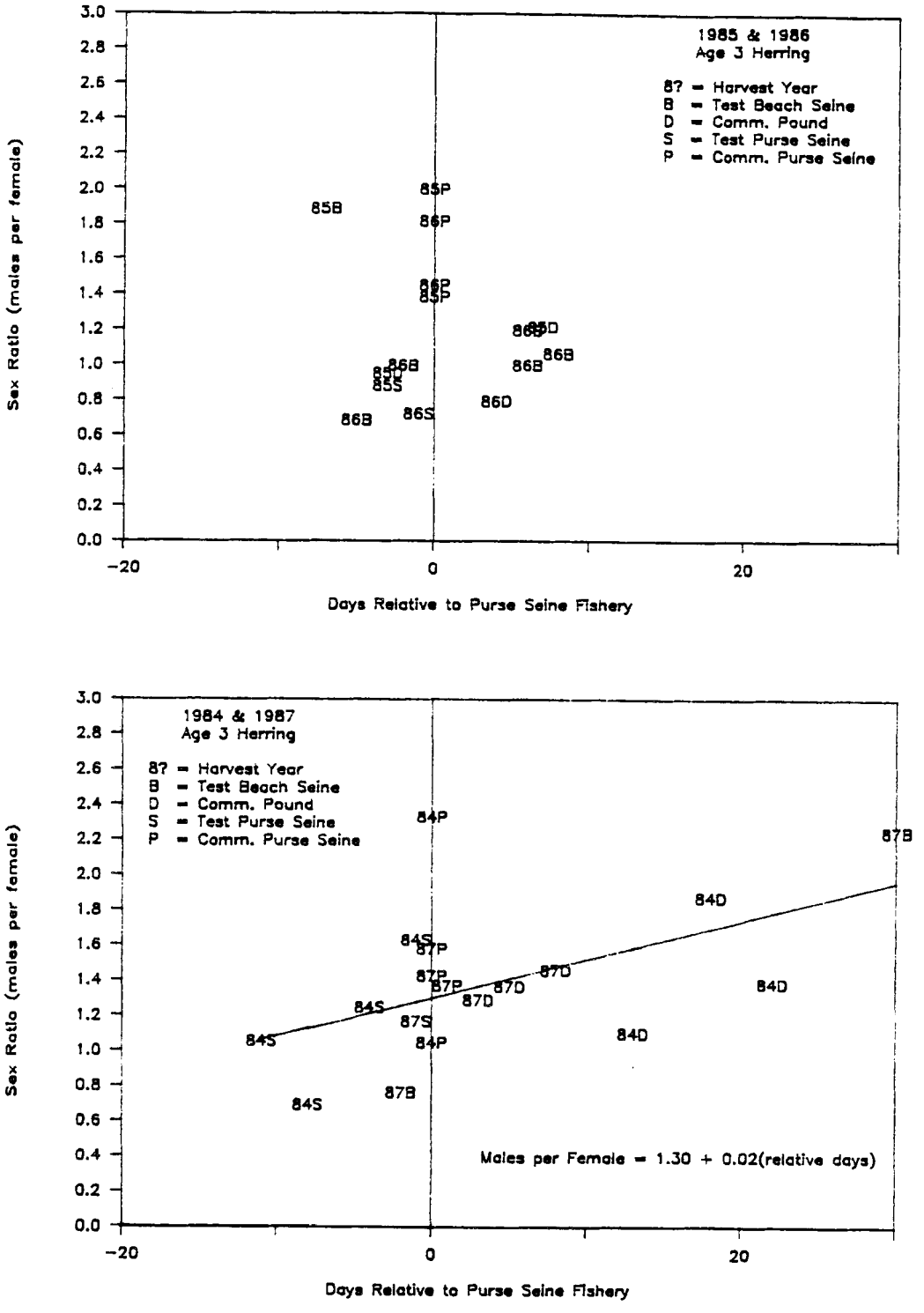

Figure 18. Age-3 Pacific herring commercial and test sample sex ratios versus time relative to initiation of the annual commercial purse seine sac roe fishery, Prince William Sound, 1985 and 1986 (above) and 1984 and 1987 (below).

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